[redacted]

Chapter 10

PERSONNEL CASUALTIES [redacted]

[redacted] INTRODUCTION [redacted]

[redacted] The three principal phenomena associated with nuclear explosions that result in casualties to personnel are blast and shock, thermal radiation, and nuclear radiation. Blast injuries may be direct or indirect; the former are caused by the high air pressure (overpressure), while the latter may be caused by missiles or by displacement of the body.

[redacted] The frequency of burn injuries resulting from a nuclear explosion is exceptionally high. Most of these are flash burns caused by direct exposure to the thermal radiation, although personnel trapped by spreading fires may be subjected to flame burns. In addition, personnel in buildings or tunnels close to ground zero may be burned by hot gases and dust entering the structure even though they are shielded adequately from direct or scattered radiation.

[redacted] The harmful effects of the nuclear radiations appear to be caused by ionization and excitation (see paragraph 6-4, Chapter 6) produced in the cells composing living tissue. As a result of ionization, some of the constituents, which are essential to the normal functioning of the cells, are altered or destroyed. As described in Section III, these changes may result in sickness that may terminate with death in some cases.

[redacted] The effects of these three phenomena on personnel are described in the succeeding three sections. A brief discussion of the effects of combinations of the phenomena is provided in Section IV.

SECTION I

[redacted] AIR BLAST [redacted]

[redacted] MECHANISMS AND CRITERIA FOR INJURY [redacted]

[redacted] Injury that results from exposure of personnel to air blast may occur from sudden changes in environmental pressure acting directly on the exposed subject, from displacement of personnel involving decelerative tumbling or impact against a rigid object, from blast-energized debris striking the individual, and from a variety of miscellaneous changes in the immediate environment. Individuals who are injured to such an extent that they are unable to perform assigned tasks are designated casualties. Such a condition typically starts almost immediately following air-blast trauma and it can be expected to last from hours to several days, depending on the nature and severity of the injury. The biological effects which may result from exposure to a blast wave are divided into four categories: (1) direct overpressure effects, (2) effects from translational forces and impact, (3) effects of blast energized debris, and (4) miscellaneous effects. These effects are discussed separately in the following paragraphs.

10-1 Direct Overpressure Effects [redacted]

[redacted] Casualties that result from direct overpressure effects are those that result from man's inability to withstand rapid changes in his environmental pressure. The body is relatively resistant to the crushing forces from air blast loading; however, large sudden pressure differences resulting from blast wave overpressure may cause serious injury. Anatomic localization of such injury occurs predominantly in air-bearing organ systems such as the lungs, gastroenteric tract, ears and perinasal sinuses. At high overpressures both early (less than 30 minutes) and delayed (30 minutes to several days) lethality will occur as a result of disruption of lung tissue. Early lethality is generally caused by interruption in the blood supply to the heart or brain as a result of air emboli entering the circulatory system

[redacted]

[redacted] from the damaged lung. Delayed lethality occurs as a result of suffocation caused by continuing hemorrhage within the lung or the development of pulmonary edema. Delayed appearance of casualties also may occur at high overpressures as a result of internal hemorrhage from ruptured organs or as a result of infection due to perforation of the intestine.

[redacted] Experiments conducted with animals indicate that direct overpressure effects depend upon the peak overpressure, duration and shape of the incident blast wave, and the orientation of the subject. Both the peak overpressure and the duration appear to be important for fast-rising blast waves that have durations less than 50 msec, whereas peak overpressure predominates for positive phase air-blast durations greater than 50 msec. If the time to peak overpressure is greater than a few milliseconds, there is a lower probability of injury because the anatomic structures will be subjected to pressure differences that occur less rapidly. This effect can take place in a structure where the pressure rises gradually due to a long fill time or it may occur near a reflecting surface where the pressure rises in "steps" as a result of a separation in the arrival times of the incident and reflected waves. In general, personnel who are oriented with the feet or head toward the oncoming blast wave will be injured less than those who are oriented with the long axis perpendicular to the blast wave. This is apparently caused by the action of the dynamic pressure to increase the load on the thorax in the latter case. A potentially more hazardous exposure condition occurs when personnel are situated against a flat surface, since normal reflection of a blast wave results in pressures two or more times the magnitude of the incident wave.

[redacted] Current criteria for direct overpressure effects, based on extrapolations from animal data, predict 50-percent casualties and one percent mortality for randomly oriented, prone personnel exposed to a long-duration fast-rising blast wave of 41 psi and one percent casualties for those exposed to 12 psi. Animal experiments and human accident cases have shown that a 50-percent incidence of eardrum rupture may be expected to occur at 16 psi, whereas one percent might be anticipated at 3.4 psi. Although in certain situations auditory acuity is imperative, eardrum rupture currently is not considered to be a disabling injury in terms of overall effectiveness to individuals in military units.

10-2 Translational Forces and Impact [redacted]

[redacted] Injuries caused by translational impact occur as a result of whole body displacement of personnel by blast winds. Anatomic localization of such injuries is not as readily definable as the case for direct overpressure effects. In instances where head impact occurs, concussion, skull fractures, and intracranial hemorrhage may result in rapid loss of consciousness and, in many cases, early lethality. By contrast, impact in which the head is not involved results in a variety of traumatic injuries such as skeletal fractures, ruptured internal organs, blood loss and, in more serious cases, the development of shock. Recovery following such injuries may be more delayed than recovery from direct overpressure effects.

[redacted] The translational and rotational velocities that are attained by personnel during the accelerative phase of blast-induced displacement depend upon the geometry of exposure and the shape and magnitude of the dynamic-pressure wave. In general, a longer duration of the positive phase of the blast wave will result in a lower peak overpressure being required to produce a given translational velocity. Therefore, larger yields will produce injuries at lower pressures (see Section I, Chapter 2). The severity of the injuries caused by displacement depends to a large extent on the nature of the decelerative phase of the motion. If deceleration occurs by an "impact" with a rigid object, resulting in a stopping distance of less than a few inches, the [redacted] probability of a serious injury is much greater than if deceleration occurs by "tumbling" over open terrain, which will result in much longer stopping distances.

[redacted] Because of the limited data available, casualty criteria for translational impact are far less certain than those for direct overpressure effects. In addition, there are marked differences in impact velocities that are associated with serious injury following head trauma compared with those for noncranial impact. Human cadaver studies indicate that 50 percent mortality may occur following head impact at velocities of 18 ft/sec, whereas large animal studies and human free-fall experience suggest that 54 ft/sec is required for 50 percent mortality when head impact is minimized. Decelerative tumbling experiments involving a limited number of animals suggest that significant mortality does not occur at translational velocities below 88 ft/sec.

[redacted] Although tentative in nature, estimates based on human accidents and animal experiments predict that a peak translational velocity of 70 ft/sec will result in 50 percent casualties for personnel when deceleration occurs by tumbling over open terrain. If translation occurs where 50 percent of the personnel impact against structures (buildings, vehicles, trees or other rigid objects) the peak translational velocity for 50 percent casualties is expected to be near 35 ft/sec. Similar figures for one percent casualties are 13 ft/sec for decelerative tumbling and 8.5 ft/sec for translation near structures.

10-3 Blast-Energized Debris [redacted]

[redacted] The effects of blast-energized debris include injuries that result from the impact of penetrating or nonpenetrating missiles energized by winds, blast overpressures, ground shock, and, in some cases, gravity. The wounding potential of blast-energized debris depends upon the nature and velocity of the moving object and the portion of the body where impact occurs. The types of injuries range from simple contusions and lacerations to more serious penetrations, fractures, crushing injuries, and critical damage to vital organs. The physical factors that determine the velocity attained by debris and thereby determine the severity of potential injury, are similar to those described for translation of personnel. When small light objects are displaced by a blast wave, they reach their maximum velocity quite rapidly, often after only a small portion of the wave has passed; therefore, the maximum velocity is not as dependent on duration as it is for large heavy objects. There are too many variables to establish definitive criteria for injury from debris.

[redacted] In the specific instance of personnel in forests, tentative casualty criteria are available based on the probability of being struck by falling trees. These criteria are related to the amount of forest damage. Fifty percent casualties are predicted at ranges where the forest damage is moderate to severe, and one percent casualties are anticipated where the damage is light (see Forest Damage Data, Chapter 15).

10-4 Miscellaneous Effects [redacted]

[redacted] Miscellaneous blast injuries are those that result from non-line-of-sight thermal phenomena, ground shock, blast-induced fires and high concentrations of dust,

- Non-line-of-sight thermal burns have been observed on animals located in open underground shelters in close proximity to nuclear explosions. Although this phenomenon is not well understood, it has been suggested that the burns resulted from contact with hot dust-laden air that was carried into the structures by the blast wave.
- Ground shock may be a serious problem for personnel in blast-hardened underground structures at close ranges. The magnitude of this hazard may be estimated from the horizontal and vertical motions of the structure, which in turn may be estimated from

[redacted] the predicted ground motions discussed in Chapter 2.

- Blast-induced fires are primarily a problem for urban areas. The likelihood of such fires depends on the amount of burning and combustible materials in the vicinity of an explosion.
- The evidence indicates that a high concentration of dust represents more of a discomfort than a serious hazard to personnel.

[redacted] With the possible exception of ground shock, currently there is inadequate information to predict the hazards associated with these miscellaneous effects reliably.

[redacted] CASUALTY PREDICTION [redacted]

10-5 Personnel in the Open [redacted]

[redacted] For most burst conditions casualties from whole body translation of personnel in the open will extend farther than those from direct overpressure hazards, excluding eardrum rupture. This is especially true for larger yield weapons because of the increased duration of the blast wave. The translation hazard will be less for personnel located in relatively open terrain than for personnel located where they may be blown against buildings, vehicles, trees or other structures. Warned personnel can reduce the translation risks by assuming a prone position, and in the case of larger yields there will be sufficient time for the fireball flash to serve as a warning. It should be noted, however, that for overhead bursts, the direct overpressure effects would be less severe for a standing man than for a prone man because of the "step" loading of the thorax in the former case.

[redacted] Unless the target area is cluttered with materials subject to fragmentation with displacement, blast-energized debris is not expected to be an overriding hazard for personnel in the open. For small yield surface bursts, however, crater ejecta may extend beyond the other blast effects, although nuclear or thermal radiation may produce casualties at greater distance. In general, the probability of being struck by flying missiles can be reduced by lying down; however crater ejecta, which is likely to be falling nearly vertically at the greater distances may strike more prone personnel than those who are standing. As in the case of blast-energized debris, the miscellaneous air blast effects are not generally expected to represent major hazards for personnel in the open.

[redacted] If a precursor form of blast wave should develop, personnel located in its proximity would probably be subjected to greater translation and debris hazards than would be expected otherwise because of the increased dynamic pressures. Burst conditions associated with precursor development are discussed in Section I of Chapter 2.

[redacted] Figures 10-1 and 10-2 show the ground distances for 50 percent and one percent casualties, respectively, from the indicated air blast effects as a function of height of burst for randomly oriented, prone personnel exposed in the open to a one kt burst. These figures were derived on the basis of the criteria and assumptions discussed earlier in this section, with the added conditions that crater ejecta was not present and no precursor formed. Since a man with a ruptured eardrum may or may not be considered a casualty depending on the tasks he is expected to perform, this effect has been removed from the other direct overpressure effects, and separate curves are provided. Two translation curves are shown in each figure and the one that is more appropriate to the existing conditions should be used. The figures show the effects for one kt, but they may be scaled to other yields by the scaling rules provided in Problem 10-1.

10-6 Personnel in a Forest [redacted]

[redacted] For personnel in a relatively dense forest, the hazard of being struck by falling and translating trees generally will override that resulting from any other air-blast effect. In addition, for

[redacted]

[redacted] most burst conditions a forest will provide significant protection from thermal radiation and will provide some shielding from nuclear radiation. Therefore, casualties resulting from forest blowdown generally will extend to greater ranges than those from any other weapon effect (direct overpressure, translation, thermal radiation, nuclear radiation, etc.). Exceptions to this general rule are casualties resulting from initial nuclear radiation associated with low yield weapons, and casualties resulting from forest fires ignited by the thermal radiation pulse.

[redacted] Casualty prediction curves for forest blowdown are given in Figures 10–1 and 10–2 as a function of height of burst and ground range for randomly oriented, prone personnel exposed to a one kt burst. These curves may be scaled to other yields by multiplying both the burst heights and the ground ranges by the four-tenths power of the yield. In general, a forest does not greatly reduce or otherwise modify a blast wave. For this reason the other curves in Figures 10–1 and 10–2, which were developed to predict air-blast casualties for personnel in the open, also may be used for personnel in a forest. A description of the particulars concerning these curves has been given in the above discussion for personnel in the open.

10–7 Personnel in Structures [redacted]

[redacted] In addition to providing shielding against thermal and nuclear radiations, blast-resistant structures such as bomb shelters, permanent gun emplacements and, to a certain extent, foxholes usually reduce the blast hazards unless personnel are located directly in the entryway of the structure. The design of these structures may, however, permit the buildup of blast overpressures to a value in excess of the overpressures outside the structure as a result of multiple reflections. Nevertheless, there is generally a lower probability of injury from direct overpressure effects inside a structure than at equivalent distances on the outside, particularly if personnel do not lean against the walls of the structure or sit or lie on the floor. This results from alterations in the pattern of the overpressure wave upon entering the structure.

[redacted] Structural collapse and damage are the major causes of casualties for personnel located in buildings subjected to air blast; for this reason, the number of such casualties can be estimated from the extent of the structural damage. Table 10–1 shows estimates of casualties in two types of buildings for three damage levels. Data from Chapter 11 may be used to predict the ground distances at which specified structural damage will occur for various yields. Collapse of a brick house is expected to result in approximately 25 percent mortality, 20 percent serious injury and 10 percent light injury to the occupants. Reinforced concrete structures, though much more resistant to blast forces, will produce almost 100 percent mortality on collapse. Casualty percentages in Table 10–1 for brick homes are based on data from British World War II experience. They may be assumed to be reasonably reliable for cases where the population expects bombing and most personnel have selected the safest places in the buildings. If there were no warning or preparation, the number of casualties would be expected to be considerably higher. To estimate casualties in structures other than those listed in Table 10–1, the type of structural damage that occurs, and the characteristics of the resultant flying objects must be considered. Broken glass may produce large numbers of casualties, particularly to an unwarned population, at overpressures where personnel would be relatively safe from other effects. Overpressures as low as one or two psi may result in penetrating wounds to bare skin.

10–8 Personnel in Vehicles [redacted]

[redacted] Personnel in vehicles may be injured as a result of the response of the vehicle to blast forces. Padding, where applicable, and the use of safety belts, helmets and harnesses can reduce

[redacted]

Table 10-1 [redacted] Estimated Casualty Production in Buildings for Three Degrees of Structural Damage [redacted]

Structural Damage	Percent of Personnel*		
	Killed Outright	Serious Injury (hospitalization)	Light Injury (no hospitalization)
1-2 story brick homes (high-explosive data from England):			
Severe damage	25	20	10
Moderate damage	<5	10	5
Light damage	–	<5	<5
Reinforced-concrete buildings (nuclear data from Japan):			
Severe damage	100	–	–
Moderate damage	10	15	20
Light damage	<5	<5	15

*These percentages do not include the casualties that may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentages of casualties expected at the maximum range where a specified structural damage occurs. See Chapter 11 for the distances at which these degrees of damage occur for various yields.

[redacted] this source of casualties significantly, at least within armored vehicles that are strong enough to resist collapse. Serious injury may result to personnel in ordinary wheeled vehicles from flying glass as well as from impact with the vehicle's interior. Comparative numbers of casualties are almost impossible to assess because of the many variables involved.

Problem 10-1 Calculation of Casualties for Personnel in the Open or in a Forest

[redacted] Figures 10-1 and 10-2 are families of curves that show 50 percent and 1 percent casualties, respectively, from the indicated air-blast effects, as a function of height of burst and distance from ground zero. The curves apply to randomly oriented, prone personnel exposed in the open to a 1 kt burst.

[redacted] *Scaling.* For yields other than 1 kt, scale as follows:

1. For the direct overpressure and ear-drum rupture curves

$$\frac{d}{d_1} = \frac{h}{h_1} = W^{1/3}$$

where d_1 and h_1 are the distance from ground zero and height of burst respectively, for 1 kt; and d and h are the corresponding distance and height of burst for a yield of W kt.

2. For the translation and forest blow-down curves

$$\frac{d}{d_1} = \frac{h}{h_1} = W^{0.4}$$

where d_1 and h_1 are the distance from ground zero and height of burst, respectively, for 1 kt; and d and h are the corresponding distance and height of burst for a yield of W kt.

[redacted] *Example* [redacted]

Given: A 50 kt weapon burst at an altitude of 860 feet over open terrain.

Find: The distance from ground zero at which translational effects would produce 50 percent casualties among prone personnel.

Solution: The corresponding height of burst for 1 kt is

$$h_1 = \frac{h}{W^{0.4}} = \frac{860}{(50)^{0.4}} = 180 \text{ ft.}$$

From Figure 10-1, at a height of burst of 180 feet, the distance from ground zero at which 50 percent casualties among personnel in the open will occur for a 1 kt burst is 660 feet.

Answer: The corresponding distance for a 50 kt weapon is

$$d = d_1 \times W^{0.4} = 660 \times (50)^{0.4} = 3150 \text{ ft.}$$

Reliability: The distances obtained from Figures 10-1 and 10-2 are estimated to be reliable to within ±15 percent for the indicated effects; however, in view of the uncertainties discussed in paragraphs 10-5 and 10-6 (e.g., the presence of debris, crater ejecta, etc.) no precise estimate of the reliability can be made for a specific situation.

Related Material: See paragraphs 10-1 through 10-6.

[redacted]

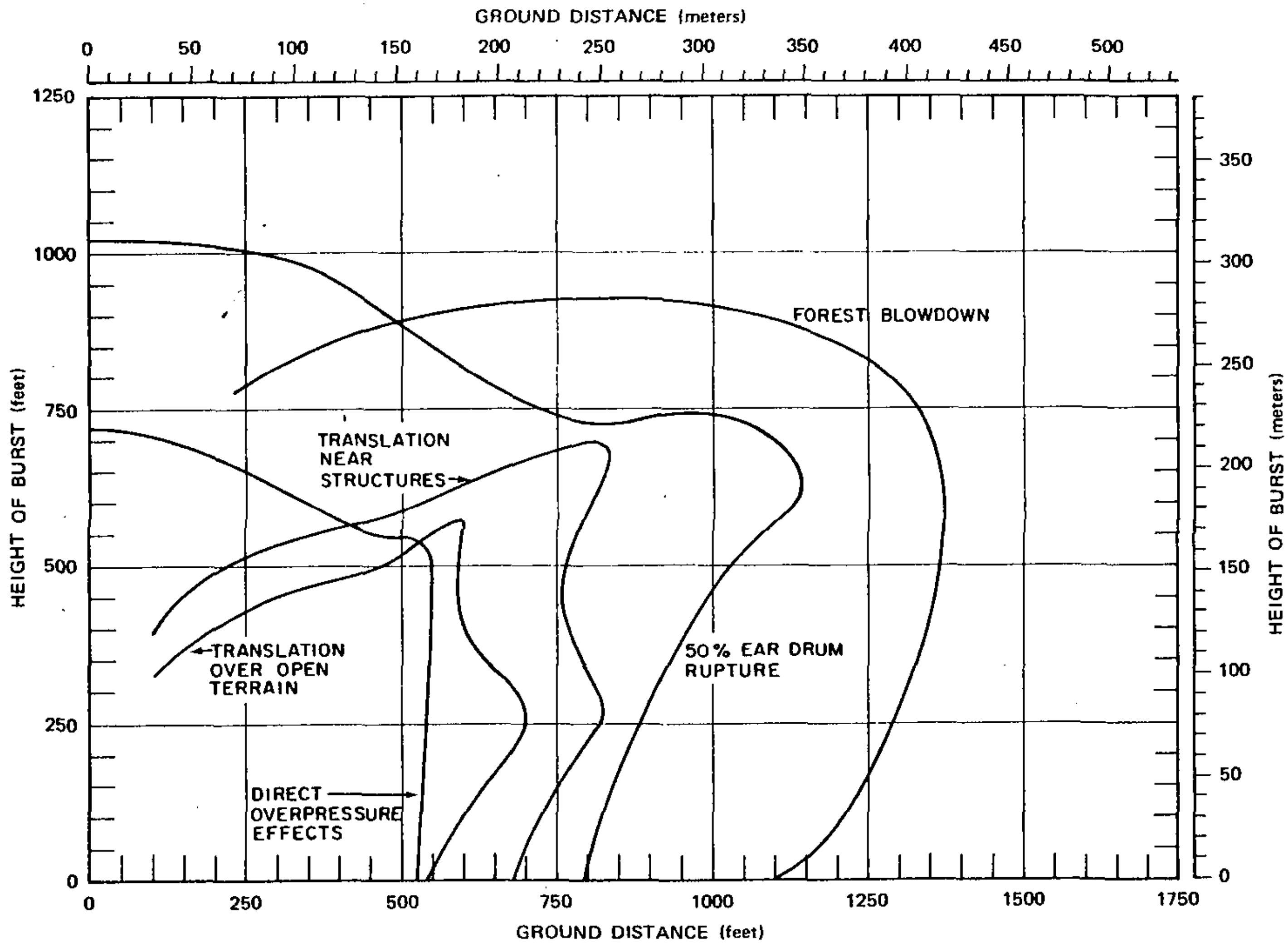


Figure 10-1. [redacted] Fifty Percent Casualties for the Indicated Blast Effects for Prone Personnel Exposed in the Open or in a Forest to a 1 kt Burst [redacted]

[redacted]

[redacted]

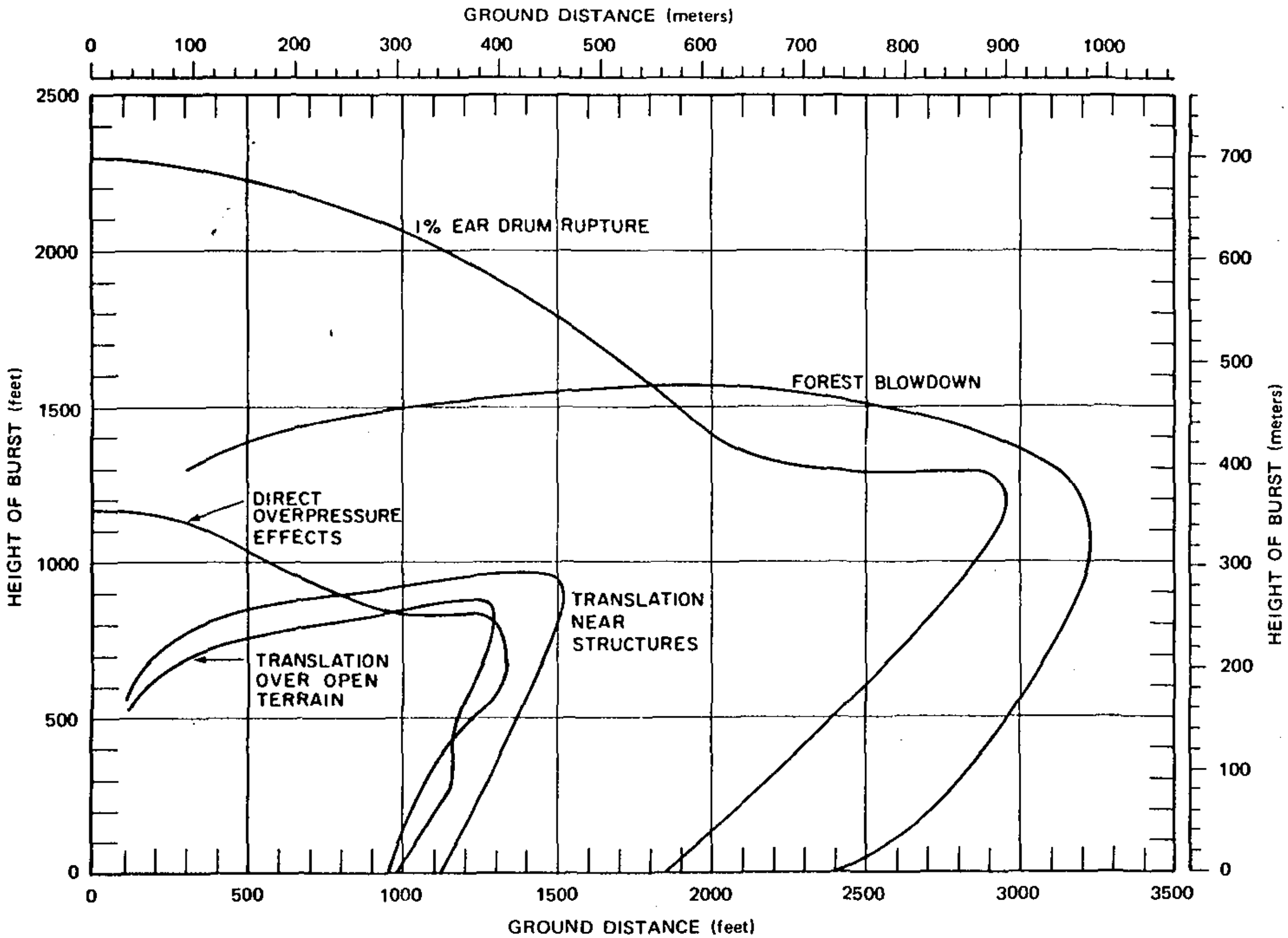


Figure 10-2. [redacted] One Percent Casualties for the Indicated Blast Effects for Prone Personnel Exposed in the Open or in a Forest to a 1 kt Burst [redacted]

[redacted]

SECTION II

[redacted] THERMAL RADIATION [redacted]

[redacted] SKIN BURNS [redacted]

[redacted] When a nuclear weapon detonates, personnel will sustain skin burns at distances that may be larger than those distances at which injury occurs as a result of blast or nuclear radiation. These burns may be produced directly by the absorption of radiant energy by the skin, or indirectly by heat transference through clothing or by ignition of the clothing. Thermal radiation is composed of light in the ultraviolet, visible and infrared regions of the spectrum and travels in a straight line at the speed of light. It is emitted within periods of a few milliseconds to several tens of seconds.

[redacted] If there is substantial material between the individual and the nuclear burst, the thermal radiation will be absorbed and no burns will be produced. Thus, persons in or behind buildings, vehicles, etc., will be shielded from the thermal pulse either partially or completely. In some instances, burns may be avoided or reduced if evasive action is taken during the delivery of the thermal pulse, since heating takes place only during direct exposure. These and other protective measures will be discussed later.

[redacted] CLASSIFICATION OF BURNS [redacted]

[redacted] Burn severity is related to the degree of elevation of skin temperature and the length of time of this elevation. Pain, a familiar warning sensation, occurs when the temperature of certain nerve cells near the surface of the skin is raised to 43°C (109°F) or more. If the temperature is not elevated to a high enough degree or for a sufficient period of time, pain will cease and no injury will occur. The amount of pain is not related to burn severity as is the classification of first degree (1°), second degree (2°) or third degree (3°) burns but it is a useful tool in warning an individual to evade the thermal pulse.

10-9 First Degree Burns [redacted]

[redacted] A skin burn is an injury to skin caused by temperature elevation following application of heat by absorption of direct thermal radiation or by transference through cloth. First degree burns are characterized by immediate pain which continues after exposure and by ensuing redness of the exposed area. The first degree burn is a reversible tissue injury; the classic example is sunburn.

10-10 Second Degree Burns [redacted]

[redacted] Second degree burns are caused by temperatures that are higher and/or of longer duration than those necessary for first degree skin burns. The injury is characterized by pain and may be accompanied by either no immediate visible effect or by a variety of skin changes including blanching, redness, loss of elasticity, swelling and blisters. After 6 to 24 hours, a scab will form over the injured area. The scab may be flexible, tan or brown, if the injury is moderate, or it may be thick, stiff and dark, if the injury is more severe. Second degree burn wounds will heal within one to two weeks unless they are complicated by infection. Second degree burns do not involve the full thickness of the skin, and the remaining uninjured cells may be able to regenerate normal skin without scar formation.

10-11 Third Degree Burns [redacted]

[redacted] Third degree burns are caused by temperatures of a higher magnitude and/or longer duration than second degree burns. The injury is characterized by pain at the peripheral, less injured areas only, since the nerve endings in the centrally burned areas are damaged to the extent that they are unable to transmit pain impulses. Immediately after exposure, the skin may appear normal, scalded, or charred, and it may lose its elasticity. The healing of third degree burns takes several weeks and always results in scar formation unless new skin is grafted over the [redacted] burned area. The scar results from the fact that the full thickness of the skin is injured, and the skin cells are unable to regenerate normal tissue.

10-12 Reduction in Effectiveness by Burns [redacted]

[redacted] The distribution of burns into three groups obviously has certain limitations since it is not possible to draw a sharp line of demarcation between first- and second-degree, or between second- and third-degree burns. Within each class the burn may be mild, moderate, or severe, so that upon preliminary examination it may be difficult to distinguish between a severe burn of the second degree and a mild third-degree burn. Subsequent pathology of the injury, however, will usually make a distinction possible. In the following discussion, reference to a particular degree of burn should be taken to imply a moderate burn of that type.

[redacted] The depth of the burn is not the only factor in determining its effect on the individual. The extent of the area of the skin which has been affected is also important. Thus, a first-degree burn over the entire body may be more serious than a third-degree burn at one spot. The larger the area burned, the more likely is the appearance of symptoms involving the whole body. Furthermore: there are certain critical, local regions, such as the hands, where almost any degree of burn will incapacitate the individual.

[redacted] Persons exposed to a low or intermediate yield nuclear weapon burst may sustain very severe burns on their faces and hands or other exposed areas of the body as a result of the short pulse of directly absorbed thermal radiation. These burns may cause severe superficial damage similar to a third degree burn, but the deeper layers of the skin may be uninjured. This would result in rapid healing similar to a mild second degree burn. Thermal radiation burns occurring under clothing or from ignited clothing or other tinder will be similar to those ordinarily seen in burn injuries of nonnuclear origin. Because of the longer duration of the thermal pulse, the differences between flash burns on exposed skin from air burst high yield weapons and burns of nonnuclear origin may be less apparent.

[redacted] BURN INJURY ENERGIES AND RANGES [redacted]

[redacted] The critical radiant exposure for a skin burn changes as the thermal radiation pulse duration and spectrum change; therefore, the critical distance cannot be determined simply from the calculated radiant exposure. The effective spectrum shifts with yield and altitude; the thermal radiation pulse is shorter for smaller yields or higher burst altitudes (see Chapter 3).

10-13 Personnel Parameters [redacted]

[redacted] The probability and severity of an individual being burned will depend upon many factors including: pigmentation, absorptive properties, thickness, conductivity and initial temperature of the skin; distance from the detonation and the amount of shielding; clothing, orientation with respect to the burst, and voluntary evasive action.

[redacted] Severity of the burn cannot be determined by temperature elevation and pulse duration alone. The energy absorbed by the skin in a normal population may vary by as much as 50 percent because of the variance in skin pigmentation. It is known that depths in skin of 0.001 to 0.002 centimeter are the sites of the initial damage that results in a burn from thermal radiation pulses and that skin temperatures of 70°C (158°F) for a fraction of a second or temperatures of 48°C (118°F) for minutes can result in burns. Skin temperatures for first degree and third degree burns are roughly 25 percent lower and higher, respectively, than those for second degree burns.

[redacted] For pulses of 0.5 second duration and longer, the amount of energy absorbed is an im-

[redacted] portant factor. Figure 10-3 shows the effect of absorptive differences of human skin as calculated from measurements of the spectral absorptance and the spectral distribution of the peak power of nuclear weapons bursts in the lower atmosphere. As shown in Figure 10-3, very dark skinned people will receive burns from approximately two-thirds the energy required to produce the same degree of burns on very light skinned people.

10-14 Burn Exposures for Unprotected Skin [redacted]

[redacted] Figure 10-4 shows ranges of radiant exposures for the probabilities of burn occurrence. The solid lines represent 50 percent probability for an average population taking no evasive action to receive the indicated type of burns. The dotted lines divide the burn probability distributions into ranges for the three burn levels with average burn probabilities of 18 percent and 82 percent assigned within these exposure ranges.

[redacted] For example, from Figure 10-4, it can be predicted that, if a normal population is exposed to the thermal pulse at distances producing between 4.5 and 6.0 calories per square centimeter from a 1 megaton weapon, 18 percent of the population will receive second degree burns and 82 percent will receive first degree burns.

[redacted] A radius from ground zero that produces areas of equal burn probability may be obtained by employing the radiant exposures for skin burn probability from Figure 10-5 and the weapon yield-distance relationship for radiant exposures from Chapter 3.

10-15 Burns Under Clothing [redacted]

[redacted] Skin burns under clothing are produced several ways: by direct transmittance through the cloth if the cloth is thin and merely acts as an attenuating screen; by heating the cloth and causing steam or volatile products to impinge on the skin; by conduction from the hot fabric to the skin; or the fabric may ignite, and consequent volatiles and flames will cause burns where they impinge on the skin.

[redacted] Heat transfer mechanisms cause burns beneath clothing as a result of heat transfer for some time after the thermal pulse ends. These burns generally involve deeper tissues than those that result from the direct thermal pulse on bare skin. Burns caused by ignited clothing also result from longer heat application, and thus will be more like burns occurring in nonnuclear weapon situations.

10-16 Body Areas Involved [redacted]

[redacted] The pattern of body area involved in thermal radiation burns from nuclear weapons will differ from the areas injured from conventional means. For weapons of 100 kt or less, where effective evasive action cannot be taken, burns would occur primarily on the directly exposed parts of the body unless the clothing ignites. First and second degree burns of the uncovered skin, and burns through thin clothing occur at lower radiant exposures than those which ignite clothing. Because of these factors, first and second degree burns for this low yield range would involve limited body area and would occur only on one side of the body. For closer distances where the direct thermal pulse produces burns and clothing ignition takes place, persons wearing thin clothing would have third degree burns over that area of the body facing the burst. This phenomenon is typically seen in persons whose clothing catches fire by conventional means.

[redacted] For the yield range 100 kt and less, persons wearing heavy clothing (in the third degree bare skin burn and clothing ignition zone) will have third degree burns on one exposed body surface and third degree burns on other areas resulting from the burning clothes prior to its removal, or full body third degree burns if the clothing cannot be removed.

[redacted]

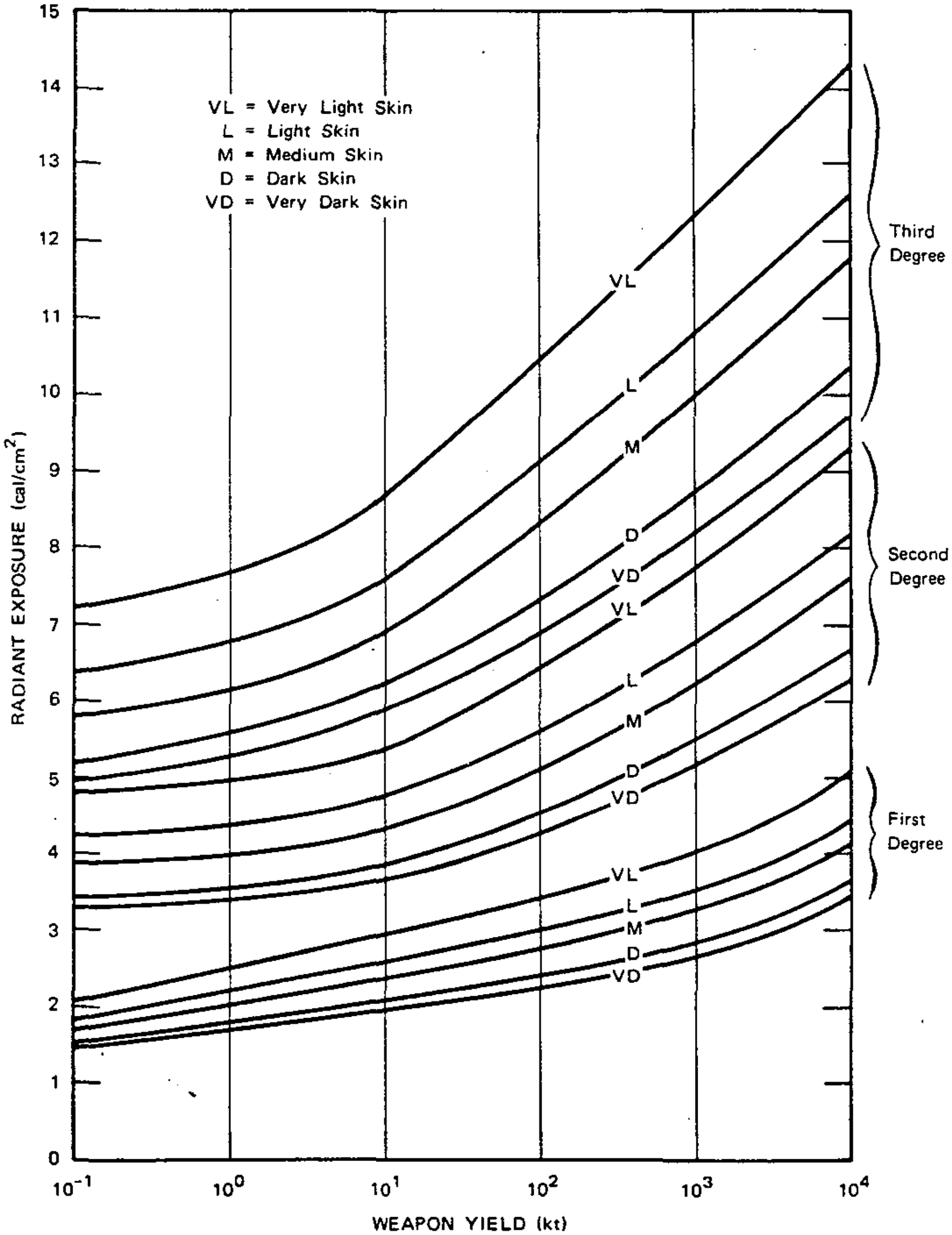


Figure 10-3. [redacted] Radiant Exposure Required to Produce Skin Burns for Different Skin Pigmentation [redacted]

[redacted]

[redacted]

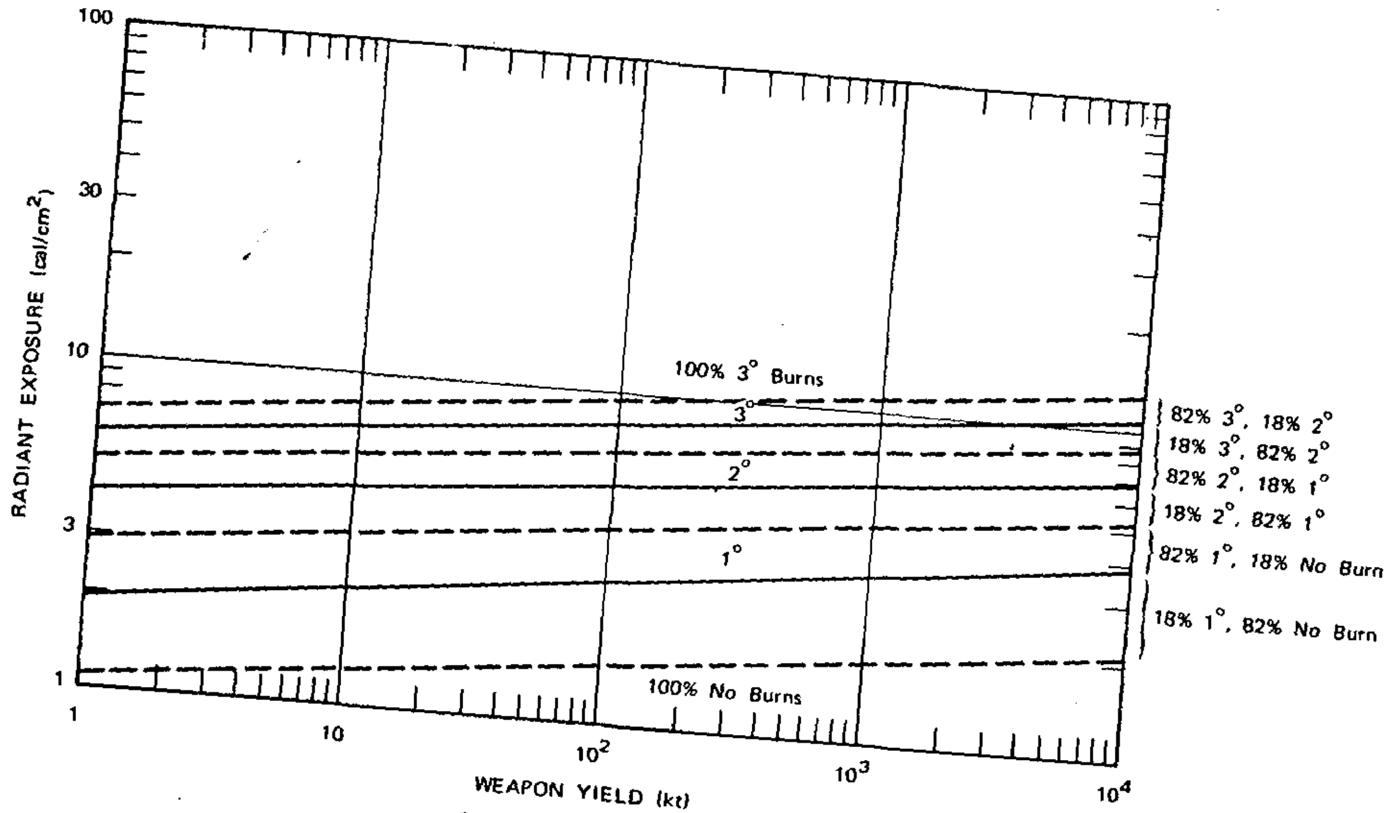


Figure 10-4. [redacted] Skin Burn Probabilities for an Average Population Taking No Evasive Action [redacted]

[redacted]

10-17 Incapacitation from Burns [redacted]

[redacted] Burns to certain anatomical sites of the body, even if only first degree, will frequently cause ineffectiveness because of their critical location. Any burn surrounding the eyes that causes occluded vision because of the resultant swelling of the eyelids, will be incapacitating. Burns of the elbows, knees, hands and feet produce immobility or limitation of motion as the result of swelling, pain or scab formation, and will cause ineffectiveness in most cases. Burns of the face and upper extremity areas are most likely to occur because these areas will more frequently be unprotected. Second or third degree burns in excess of 20 percent of the surface area of the body should be considered a major burn and will require special medical care in a hospital.

[redacted] Shock is a term denoting a generalized state of severe circulatory inadequacy. It will result in ineffectiveness and if untreated may cause death. Third degree burns of 25 percent of the body and second degree burns of 30 percent of the body will generally produce shock within 30 minutes to 12 hours and require prompt medical treatment. Such medical treatment is complicated and causes a heavy drain on medical personnel and supply resources.

10-18 Modification of Injur[redacted]

[redacted] Timely evasion can be effective in reducing burns with weapons yields of 100 kt and greater. The length of time between the burst and the point at which critical radiant exposure occurs increases with increasing yields, permitting personnel to react prior to receiving severe burns. With yields of less than about 100 kt, or for high altitude bursts of larger yields, the thermal pulse is too short for personnel to react and take cover. Since pain occurs at low radiant exposures and at lower temperatures than those that cause first degree burns, it is the initial sensation that occurs, and involuntary action due to pain can be expected instinctively. More effective action can be expected with proper training. Figure 10-5 illustrates the effect of evasion on the production of burns.

[redacted] Personnel in the shadow of buildings, vehicles, or other objects at the time of detonation will be shielded from the pulse and will not be burned.

[redacted] EFFECTS OF THERMAL RADIATION ON THE EYES [redacted]

[redacted] Exposure of the eye to a bright flash of a nuclear detonation produces two possible effects; flashblindness and/or retinal burns.

10-19 Flashblindness [redacted]

[redacted] Flashblindness (dazzle) is a temporary impairment of vision caused by the saturation of the light sensitive elements (rods and cones) in the retina of the eye. It is an entirely reversible phenomena which will normally blank out the entire visual field of view with a bright afterimage. Flashblindness normally will be brief, and recovery is complete.

[redacted] During the period of flashblindness (several seconds to minutes) useful vision is lost. This loss of vision may preclude effective performance of activities requiring constant, precise visual function. The severity and time required for recovery of vision are determined by the intensity and duration of the flash, the viewing angle from the burst, the pupil size, brightness necessary to perform a task and the background, and the visual complexity of the task. Flashblindness will be more severe at night since the pupil is larger and the object being viewed and the background are usually dimly illuminated.

[redacted] Flashblindness may be produced by scattered light and does not necessarily require eye focusing on the fireball.

10-20 Retinal Burns [redacted]

[redacted] A retinal burn is a permanent eye injury that occurs whenever the retinal tissue is heated.

[redacted]

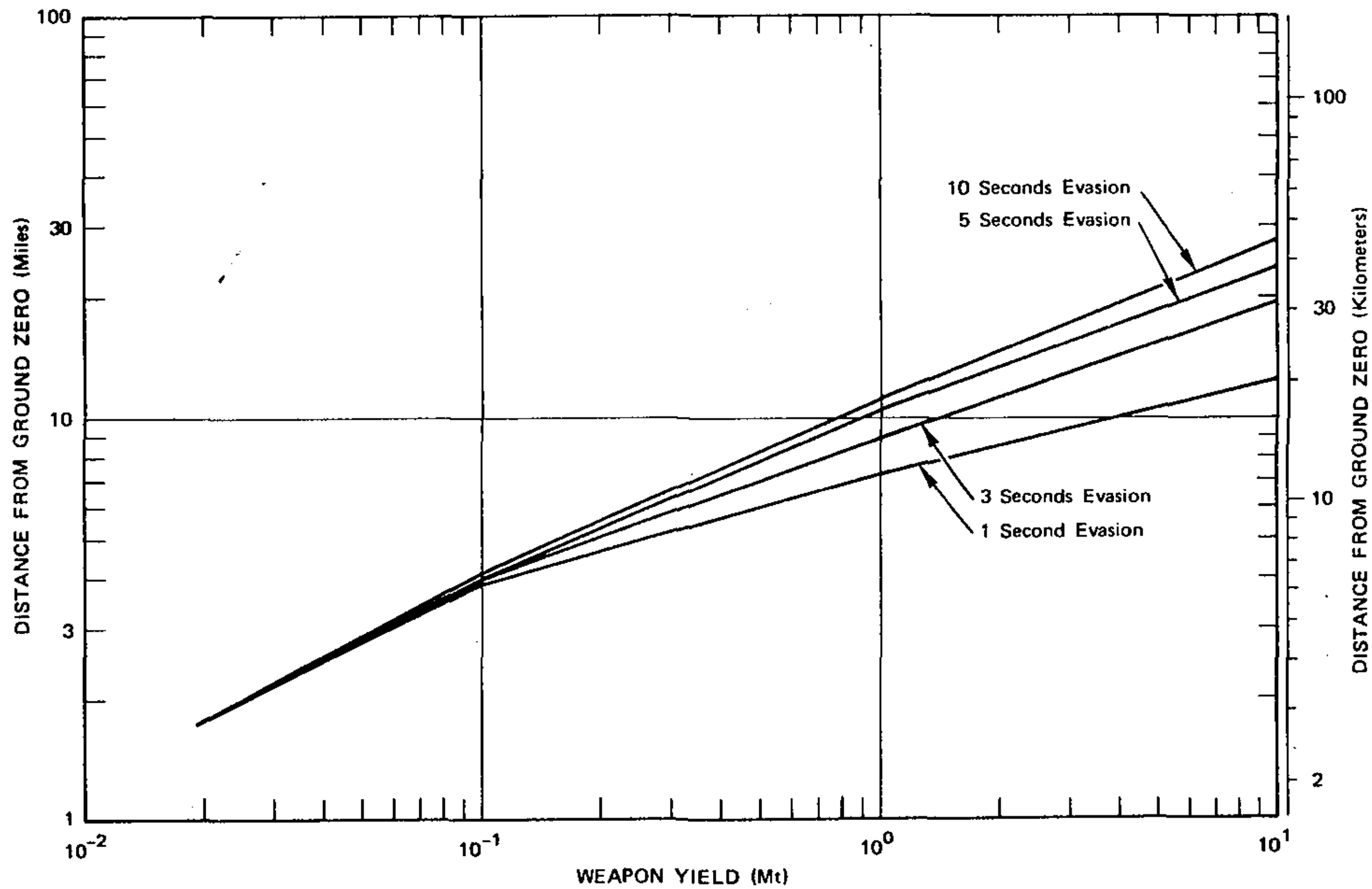


Figure 10-5. [redacted] Distance Thresholds for Second Degree Burns for Various Evasion Times [redacted]

[redacted]

[redacted] excessively by the focused image of the fireball within the eye. The underlying pigmented cells absorb much of the light and raise the temperature in that area. A temperature elevation of 12–20°C (22–36°F) in the eye produces a thermal injury which involves both the pigmented layer and the adjacent rods and cones, so the visual capacity is permanently lost in the burned area. The natural tendency of personnel to look directly at the fireball tends to increase the incidence of retinal burns.

[redacted] Retinal burns can be produced at great distances from nuclear detonations, because the probability of eye burns does not decrease as the square of the distance from the detonation as is true of many other nuclear weapons effects. Theoretically, the optical process of image formation within the eye negates the inverse square law and keeps the intensity per unit area on the retina a constant, regardless of the distance. However, meteorological conditions and the fact that the human eye is not a perfect lens, all contribute toward reducing the retinal burn hazard as the distance is increased between the observer and the detonation.

[redacted] Explosion yields greater than one megaton, and at heights of burst greater than about 130 kilofeet may produce retinal burns as far out as the horizon on clear nights. Bursts above 490 kilofeet probably will not produce any retinal burns in personnel on the ground unless the weapon yield is greater than 10 Mt.

(U) A retinal burn normally will not be noticed by the individual concerned if it is off the central axis of vision; however, very small burned areas may be noticeable if they are centrally located. Personnel generally will be able to compensate for a small retinal burn by learning to scan around the burned area.

10-21 Modification of Thermal Effects on the Eye [redacted]

[redacted] The thermal pulse from a nuclear weapon is emitted at such a rapid rate that any device designed to protect the eye must close extremely fast (<100 μsec) to afford a sure degree of protection for all situations. During the daytime, when the pupil is smaller and objects are illuminated brightly, the 2 percent transmission gold goggle/visor will reduce flashblindness recovery times to acceptable levels. At present, this goggle is unsatisfactory for use at night, and there is no protective device that is adequate for night use.

[redacted] The blink reflexes of the eye are sufficiently fast (~0.2 second) to provide some protection against weapons greater than 100 kt detonated below about 130 kilofeet. The blink time is too slow to provide any appreciable protection for smaller weapon yields or higher burst altitudes.

[redacted] When personnel have adequate warning of an impending nuclear burst, evasive action including closing or shielding the eyes will prevent flashblindness and retinal burns.

10-22 Safe Separation Distance Curves [redacted]

[redacted] Figures 10–6 through 10–10 present flashblindness and retinal burn curves for a number of burst heights as a function of weapon yields and safe separation distance, e.g., that distance where personnel will not receive incapacitating eye injuries. The retinal burn curves show distances that current data show to be safe. The curves for flashblindness were specifically designed for pilots of strategic bombers, where a pilot can effectively read his instruments and complete his mission after a temporary 10 second complete loss of vision. These curves are also applicable to any task where the same criteria of dim task lighting, visual demands, and the 10 second visual loss can be applied. Data are not available for specific distances at which flashblindness will not occur.

[redacted] It should be noted that the flashblindness and the retinal burn safe separation distances do not bear the same relationship to one another as the yield changes. In circumstances that require determination of complete eye safety (realizing

[redacted]

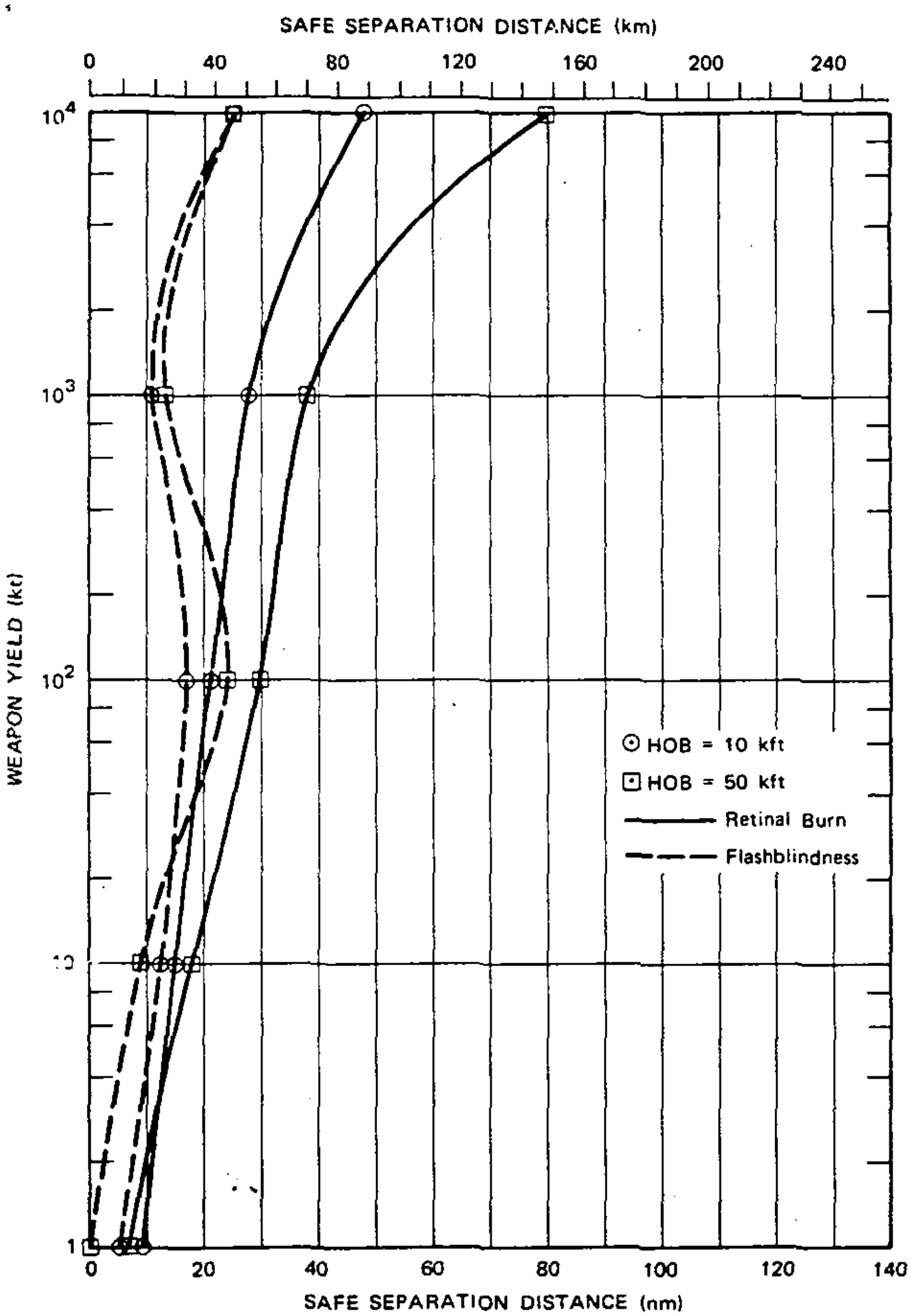


Figure 10-6. [redacted] Safe Separation Distances, for an Observer on the Ground, from Bursts at 10 kft and 50 kft During the Day [redacted]

[redacted]

[redacted]

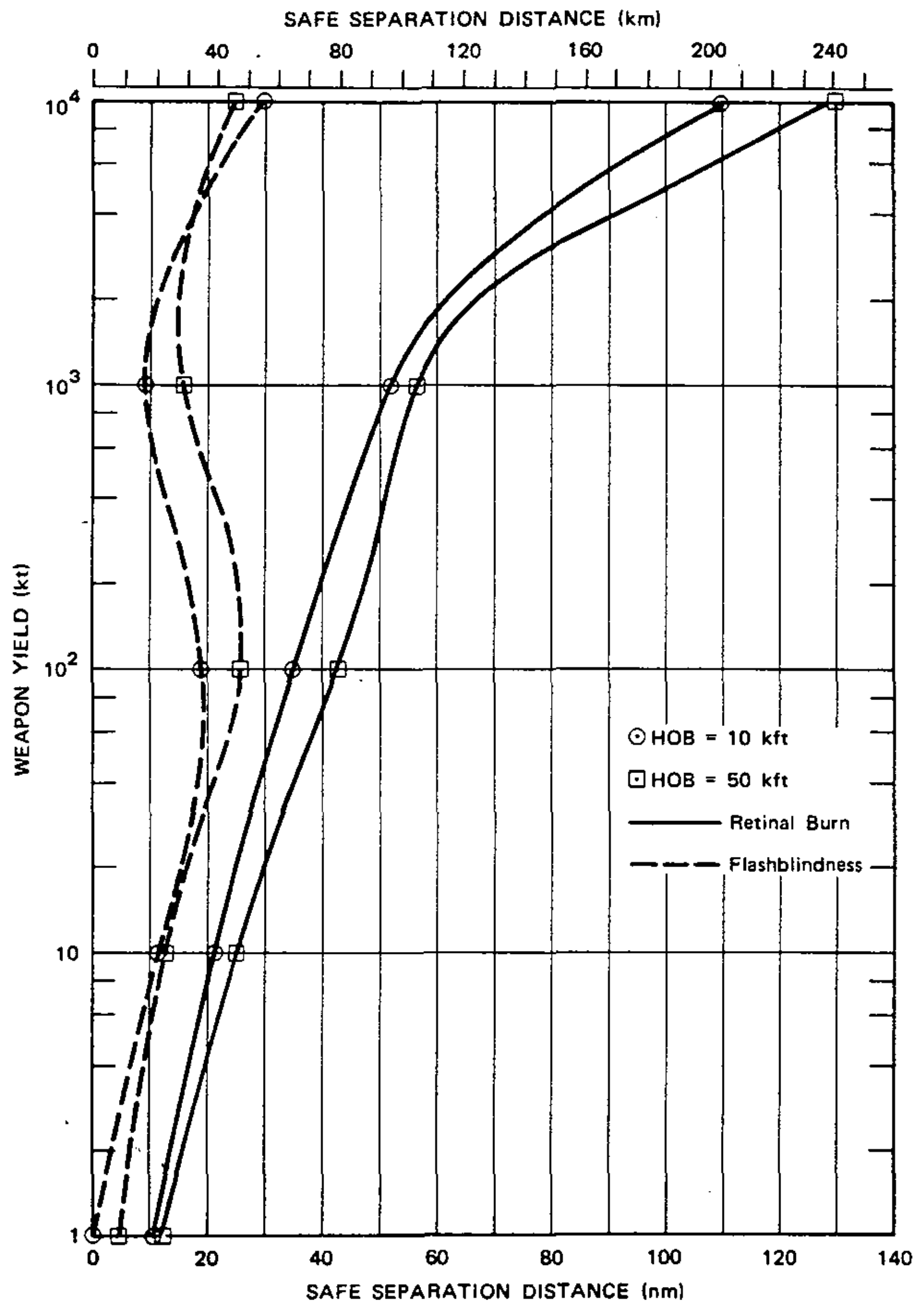


Figure 10-7. [redacted] Safe Separation Distance, for an Observer at 50 kft, from Bursts at 10 kft and 50 kft During the Day [redacted]

[redacted]

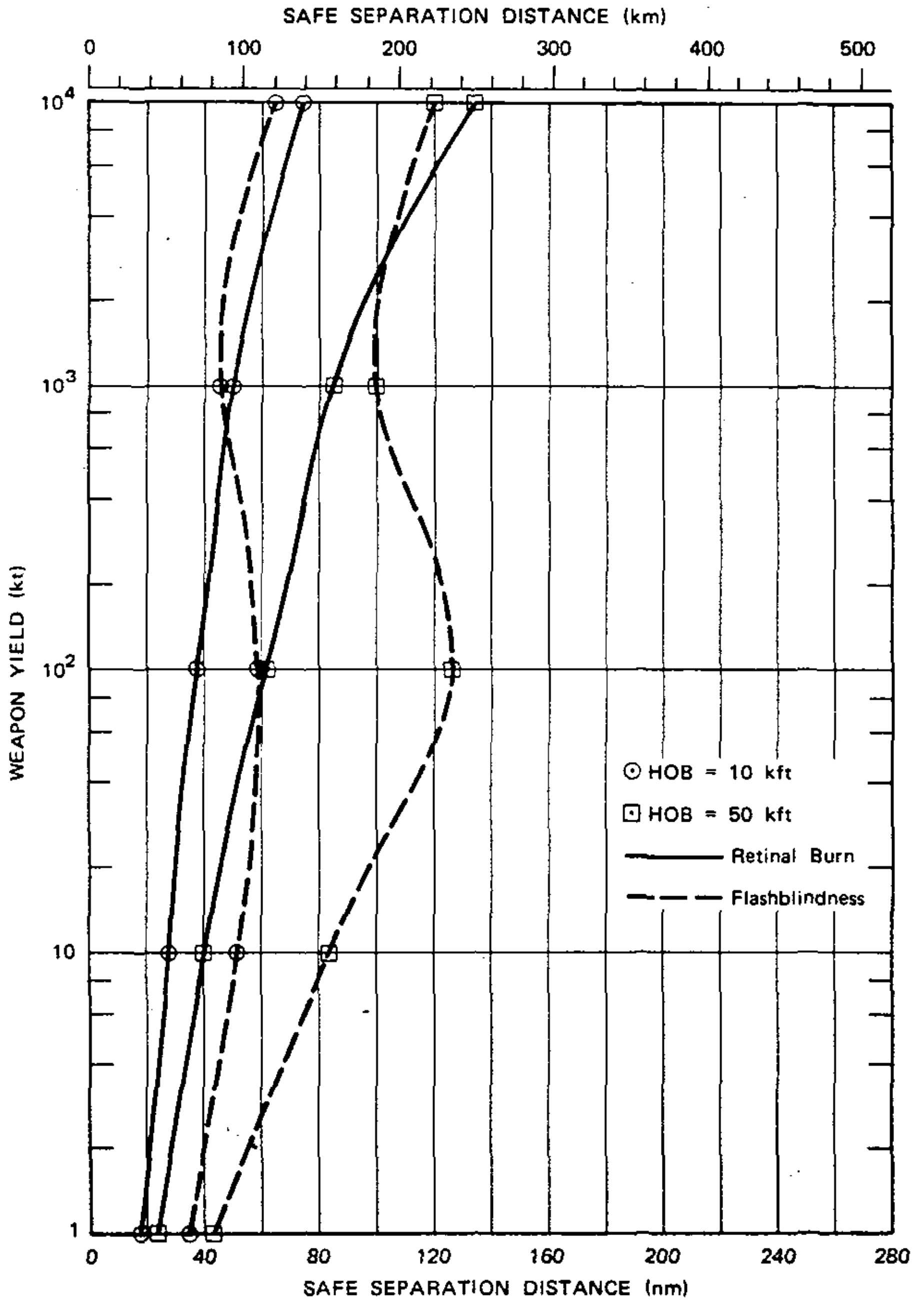


Figure 10-8. [redacted] Safe Separation Distance, for an Observer on the Ground, from Bursts at 10 kft and 50 kft, During the Night [redacted].

[redacted]

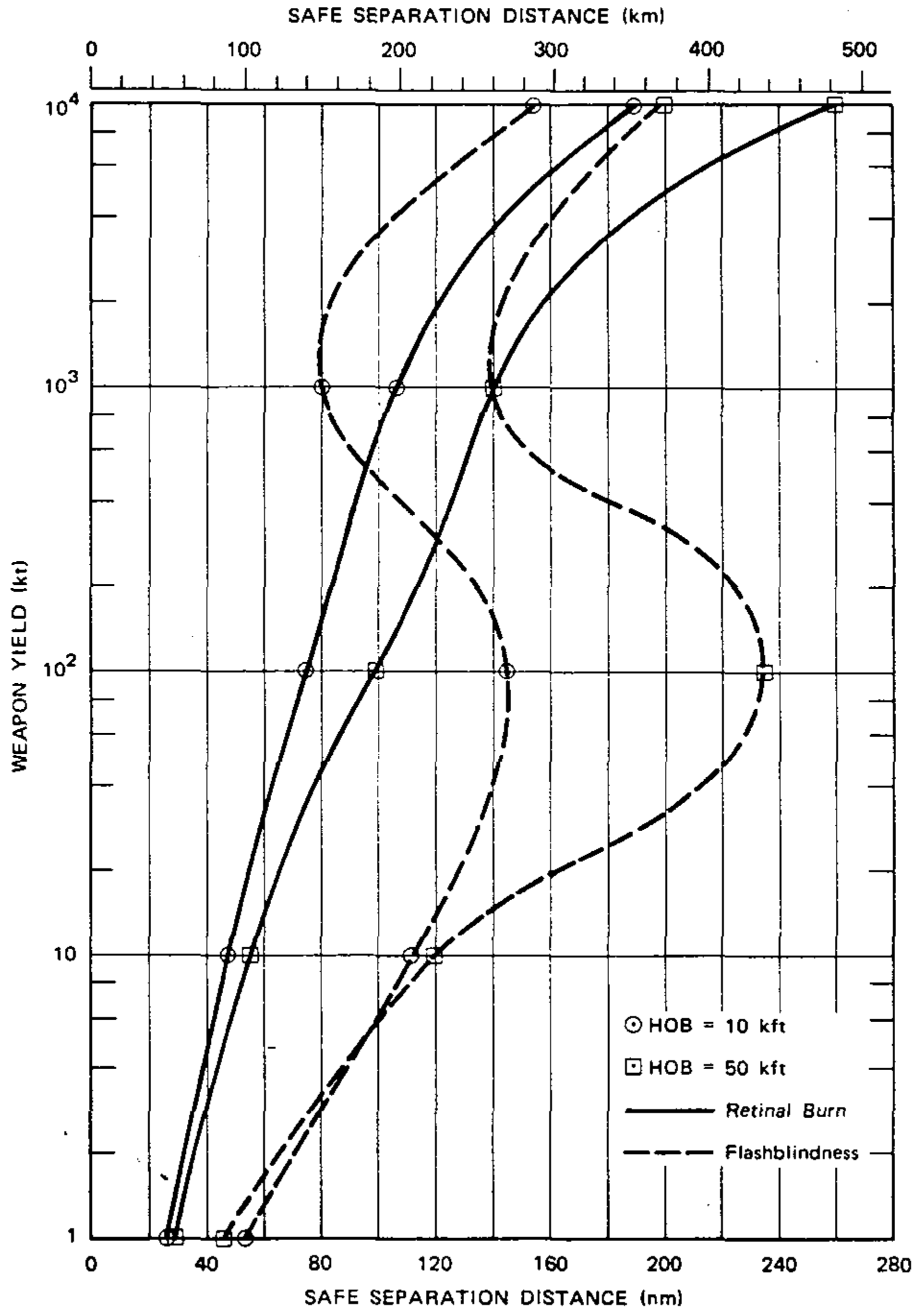


Figure 10-9. [redacted] Safe Separation Distance, for an Observer at 50 kft, from Bursts at 10 kft and 50 kft, During the Night [redacted]

[redacted]

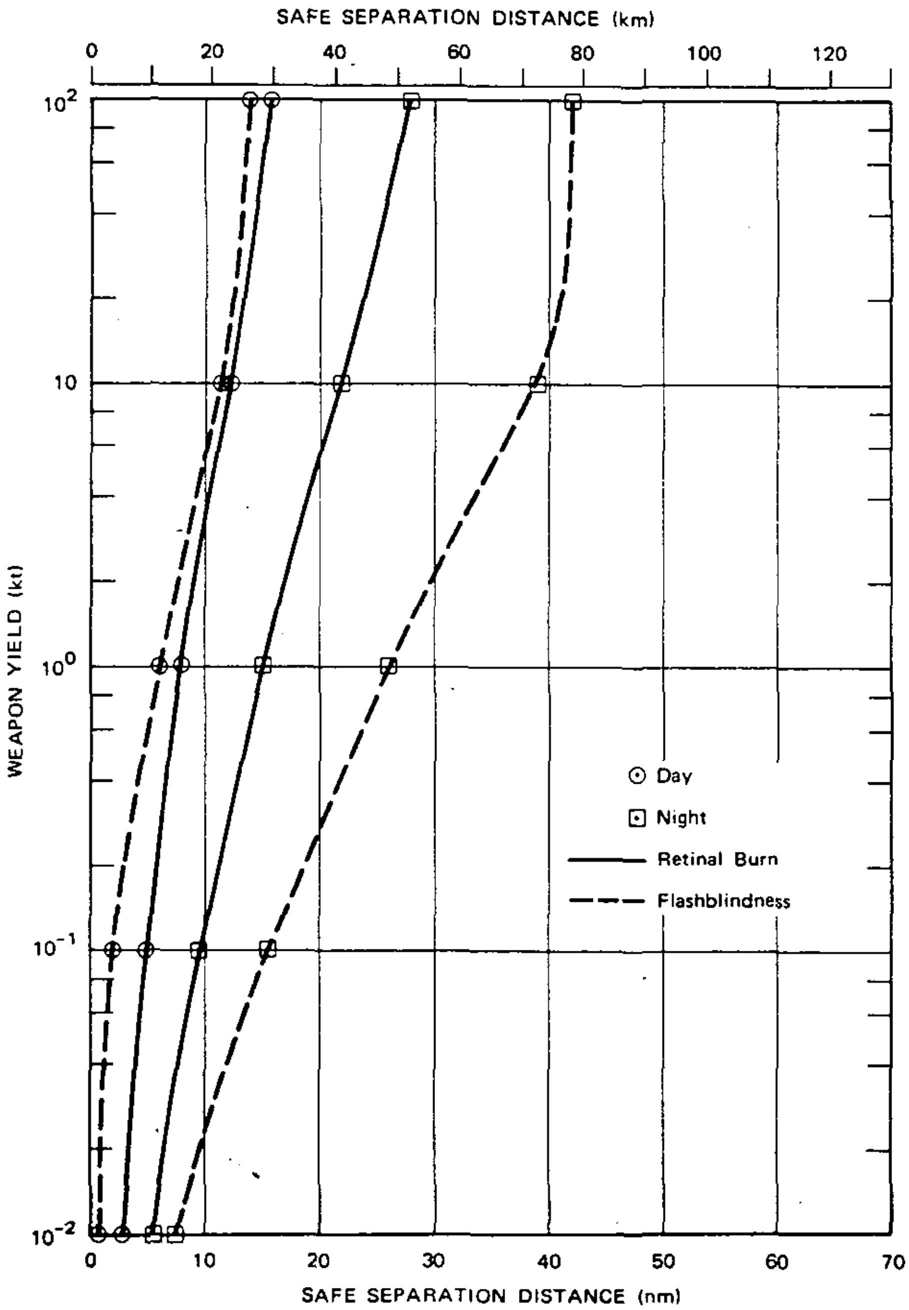


Figure 10-10. [redacted] Safe Separation Distance, for an Observer on the Ground, from Low Yield Weapons Exploded at 1,000 ft Height of Burst [redacted]

[redacted] the 10 second loss of vision criterion in the flashblindness curves), the retinal burn or flashblindness curve that shows the effect that occurs at the greatest distance from the burst should be used. For example, using Figure 10–8 and a 50 kilofeet height of burst, to determine the distance from a nuclear detonation where there will be no incapacitating eye effects, the flashblindness curve is the limiting factor up to about 3 megatons, then the retinal burn curve becomes the limiting factor.

[redacted] In instances where only permanent eye damage is of interest, and the temporary loss of vision from flashblindness is not of concern, only the retinal burn curves should be used.

[redacted] The retinal burn curves show distances at which a nuclear burst will not produce retinal burns provided the eye can blink within 250 milliseconds. A faster blink time would not change the distances appreciably. The curves are based on a very clear day (60 mile visual range). For a cloudy day with a 5 mile visual range, the safe separation distances would be reduced by about 50 percent.

SECTION III

[redacted] NUCLEAR RADIATION [redacted]

[redacted] The injurious effects of nuclear radiations (gamma rays, neutrons, beta particles and alpha particles) on the human target represent a phenomenon that is completely absent from conventional explosives. Since there has not been sufficient experience with humans in the exposure ranges of military interest, the material presented below is based largely on animal experimentation that has been extrapolated to the area of human response. Even if sufficient human data were available, they would be expected to show similar responses and the same wide range of biological variability within species as is seen in animals. Data are presented in terms of absorbed dose at or near the body surface in order to relate to source and transport factors given in Chapter 5. Current radiobiological research results are frequently reported as *midline tissue dose* in rad, a dose significantly lower than doses measured by radiac instruments and absorbed within those volumes near the surface of the body that faces toward the source. For nuclear weapon radiation, the midline tissue doses would be approximately 70 percent of the body surface doses presented in the following paragraphs.

[redacted] INITIAL RADIATION [redacted]

[redacted] Neutrons and gamma rays in various proportions are responsible for biological injury from initial radiation. For military purposes, and until further animal experimentation provides evidence to the contrary, it must be assumed that damage to tissue is directly proportional to the absorbed dose regardless of whether it is delivered by neutrons or gamma rays. For effects of military interest, it is assumed that injury from a neutron rad is equal to that from a gamma rad, and that one rad absorbed dose results from exposure to one roentgen.

10-23 Radiation Sickness [redacted]

[redacted] Individuals exposed to whole body ionizing radiation may show certain signs and symptoms of illness. The time interval to onset of these symptoms, their severity, and their duration generally depend on the amount of radiation absorbed, although there will be significant variations among individuals. Within any given dose range, the effects that are manifested can be divided conveniently into three time phases: initial, latent, and final.

[redacted] During the initial phase, individuals may experience nausea, vomiting, headache, dizziness and a generalized feeling of illness. The onset time decreases and the severity of these symptoms increases with increasing doses. During the latent phase, exposed individuals will experience few, if any, symptoms and most likely will be able to perform operational duties. The final phase is characterized by frank illness that re-

[redacted] quires hospitalization after exposure to the higher doses. In addition to the recurrence of the symptoms noted during the initial phase, skin hemorrhages, diarrhea and loss of hair may appear, and, at high doses, seizures and prostration may occur. The final phase is consummated by recovery or death. At doses above 1000 rad, death may be expected in all cases. Maximum recovery of survivors exposed to lower doses may require as much as three to six months time. With the foregoing in mind, Table 10-2 is presented as the best available summary of the effects of various whole-body dose ranges of ionizing radiation in human beings.

10-24 Incapacitation [redacted]

[redacted] Direct effects of high doses of external radiation administered over a short time period *may result in loss of ability to perform purposeful actions.* At doses greater than 2,000 rads, an acute collapse may occur in a short time. The collapse may persist from several minutes to a few hours. A period of relatively normal performance capability will then occur; however, after some *time permanent incapacitation and* death will result. This early incapacitation, followed by a temporary period of recovery, is defined as early transient incapacitation (ETI). Following this transient incapacitation, exposed personnel *may* be reasonably well oriented, lucid, and able to perform tasks requiring coordination of visual and auditory sensory input. The duration of early transient incapacitation is believed to be dose dependent, i.e., the greater the dose, the longer the transient incapacitation phase. The duration of the temporary period of effec-

Table 10-2 [redacted] Response to Single Whole-Body Exposures [redacted]

	100-200 Rad	200-400 Rad	400-600 Rad	600-1000 Rad	1000-2500 Rad
Initial Phase					
1. Onset of symptoms after irradiation	3-6 hrs	1-6 hrs	1/2 to 6 hrs	1/4 to 4 hrs	5-30 min
2. Duration of phase	≤1 day	1-2 days	1-2 days	≤2 days	≤1 day
Latent Phase					
1. Onset after irradiation	≤1 day	1-2 days	1-2 days	≤2 days	≤1 day
2. Duration of phase	≤2 weeks	2-4 weeks	1-2 weeks	5-10 days	0-7 days*
Final Phase					
1. Onset of symptoms after irradiation	10-14 days	2-4 weeks	7-14 days	5-10 days	4-8 days
2. Duration of phase	4 weeks	2-8 weeks	1-8 weeks	1-4 weeks	2-10 days
3. Time from irradiation to death	—	4-12 weeks	2-10 weeks	1-6 weeks	4-14 days
4. Deaths (% of those exposed)	No deaths	0-30%	30-90%	90-100%	100%

*At the higher doses within this range there may be no latent period.

[redacted] tiveness is inversely related to the dose. At doses in excess of 15,000 rads, most individuals will experience permanent complete incapacitation within a few minutes post-irradiation, followed by death within 2 to 24 hours.

[redacted] Figures 10-11 through 10-15 list estimated personnel effectiveness at various times following acute radiation doses of 1,400 rads and greater. It should be noted that incapacitation, or performance, decrement, and not death, is the endpoint of interest in these figures.

10-25 Modification of Injury [redacted]

[redacted] When only a portion of the body is exposed to radiation, the effects are significantly less than those described in the preceding two sections. The reduction of the effects depends on the magnitude of exposure and the particular portion of the body that is exposed. Thus, partial shielding afforded by natural or man-made structures can be expected to decrease the severity of radiation injury.

[redacted] Considerable effort has been expended in searching for compounds that will reduce the extent and seriousness of radiation injury when they are administered prior to exposure. At present, there is no satisfactory compound available for issue, although research continues in this area.

[redacted] Treatment of radiation injury is support-[redacted] nature. The treatment is based primarily on symptomology rather than measured or estimated dose received by the individual.

10-26 Military Assumptions [redacted]

[redacted] In order to apply the material above to other than single exposures, it may be assumed that multiple exposures within any 24-hour period are arithmetically additive. This assumption is necessary because the information concerning the results of multiple exposures is limited.

[redacted] Although there is reason to believe that r[redacted]very from radiation exposure(s) is never really complete (i.e., some residual injury not necessarily affecting effectiveness remains), it may be assumed for military planning purposes that recovery is complete in approximately 30 days following a single sublethal exposure. Table 10-2 lists more specific information regarding durations of ineffectiveness under varying exposure conditions.

[redacted] RESIDUAL RADIATION [redacted]

[redacted] The importance of residual radiation as a source of injury to personnel depends upon the necessity for military operations in or near areas of local fallout. Time of arrival, weathering, and decay of the deposited fallout all result in a constantly changing rate of external protracted exposure to personnel in contrast to the almost instantaneous exposure to initial radiation. An added hazard results from the presence of small, finely divided, radioactive particulate sources that can contribute to injury by both external and internal irradiation.

10-27 External Hazards [redacted]

[redacted] Gamma rays present the major militarily significant external hazard from residual radiation. Effects on personnel will range from those described previously for initial radiation exposures (in new, high dose-rate, fallout fields) to lesser effects for the same total exposure in low dose-rate fields.

[redacted] Beta burns can occur if fallout particles remain on the skin for periods of hours or more. They will occur most frequently when the fallout particles are deposited on moist skin areas, body crevices, in the hair, or when the particles are held in contact by clothing. While minor skin symptoms may occur during the first 48 hours following exposure, the appearance of burns will be delayed two weeks or more after exposure. Severity of the burns is a function of the radioactivity of the fallout particles and the time period during which they adhere to the body. Personnel ineffectiveness will depend on the severity of the burn and its location on the body.

[redacted]

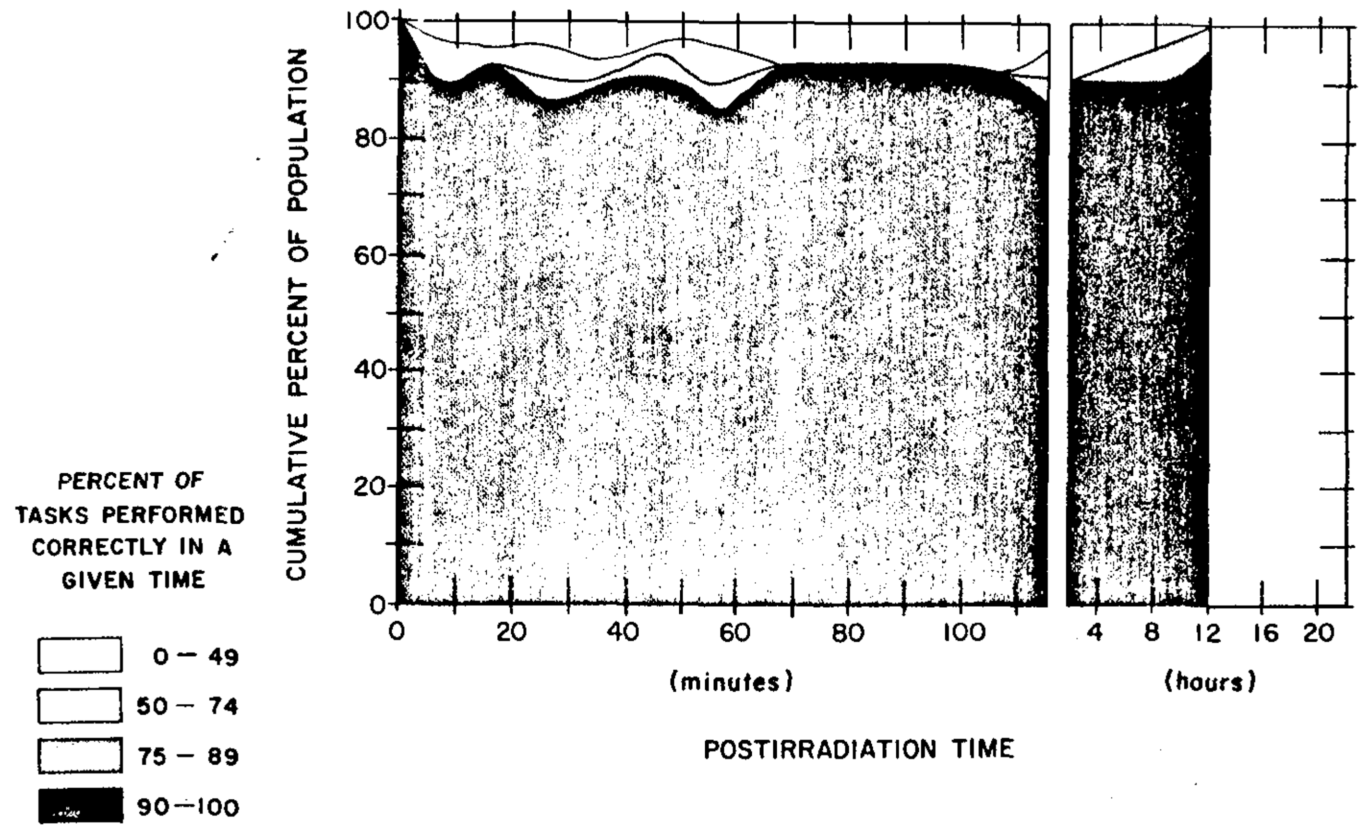
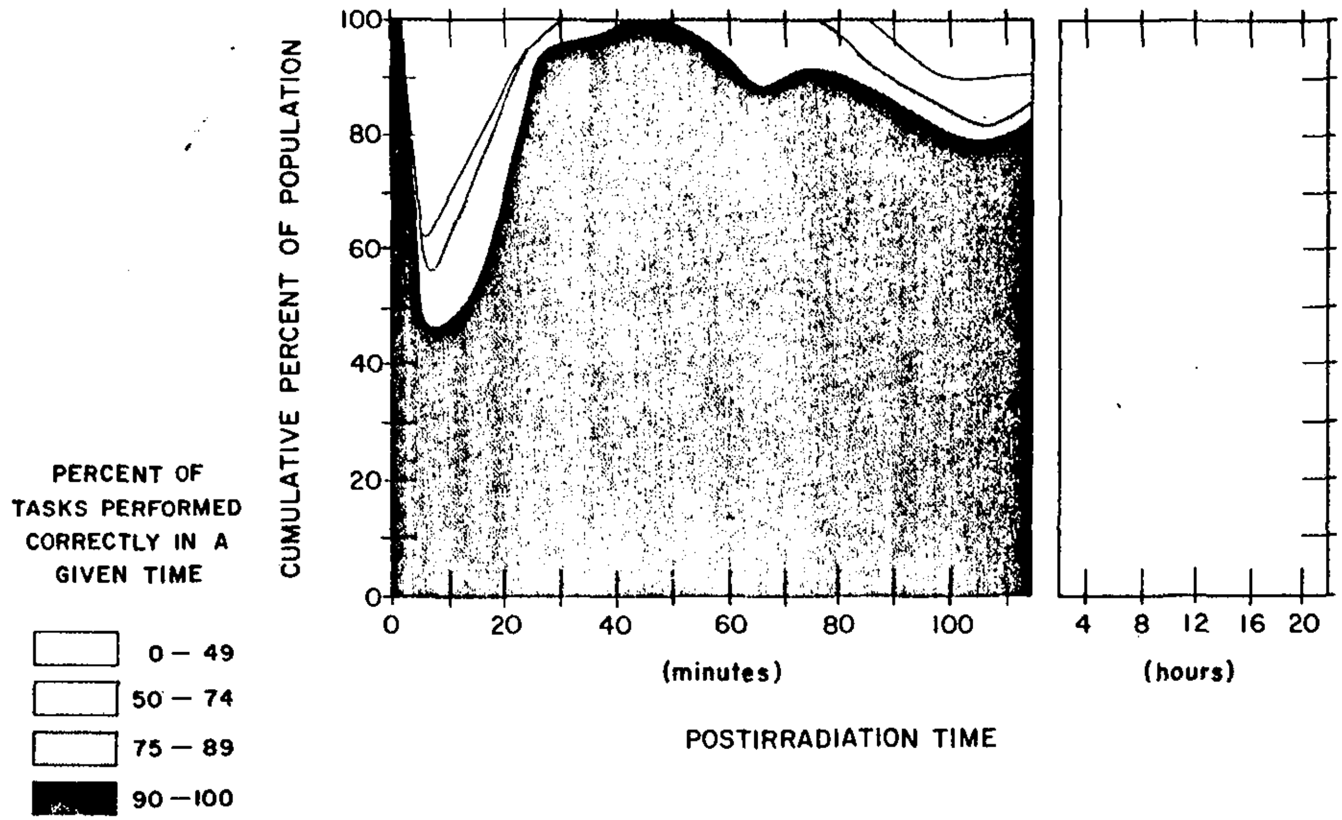


Figure 10-11. [redacted] Personnel Effectiveness After Exposure to 1,400 rads [redacted]

[redacted]

[redacted]



[redacted]

Figure 10-12. [redacted] Personnel Effectiveness After Exposure to 2,800 rads [redacted]

[redacted]

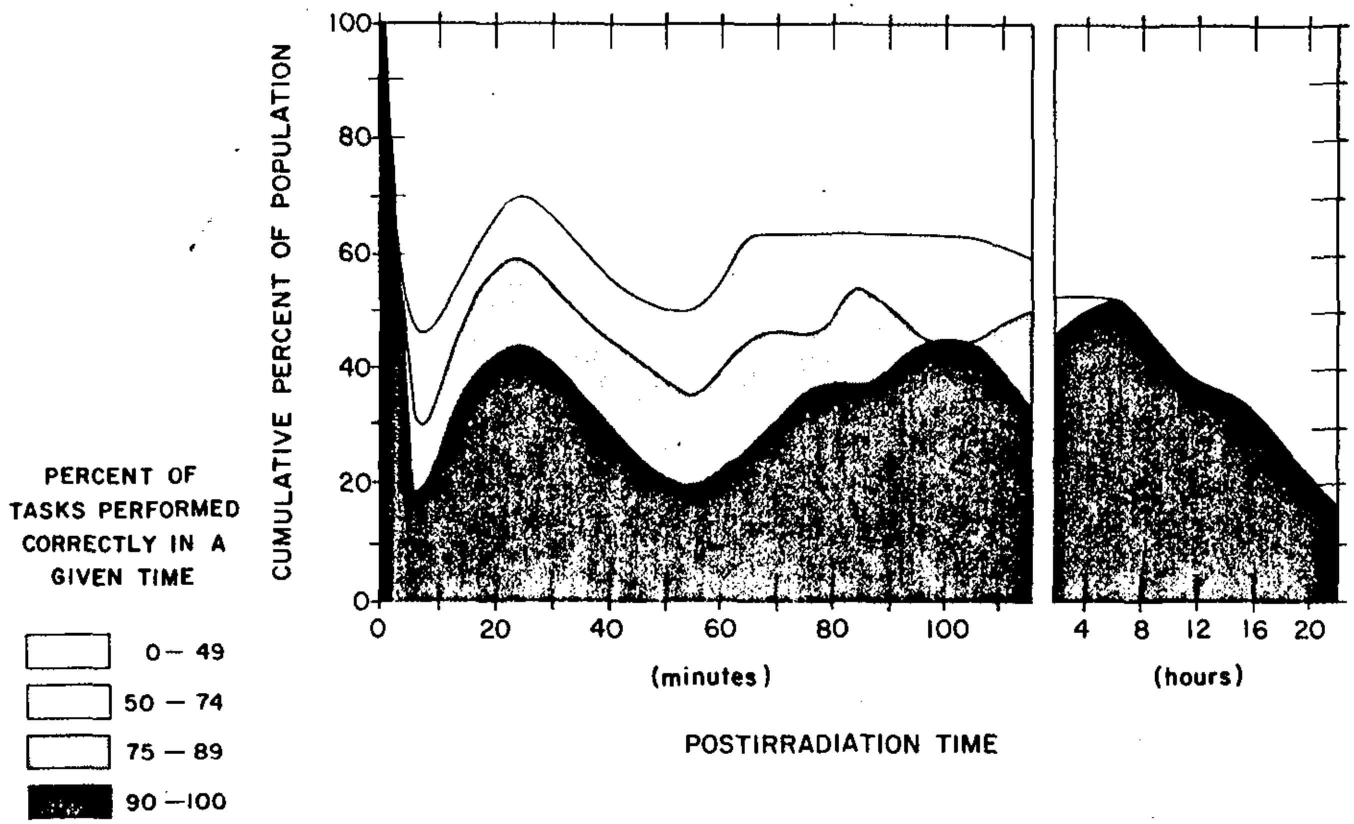


Figure 10-13. [redacted] Personnel Effectiveness After Exposure to 7,000 rads [redacted]

[redacted]

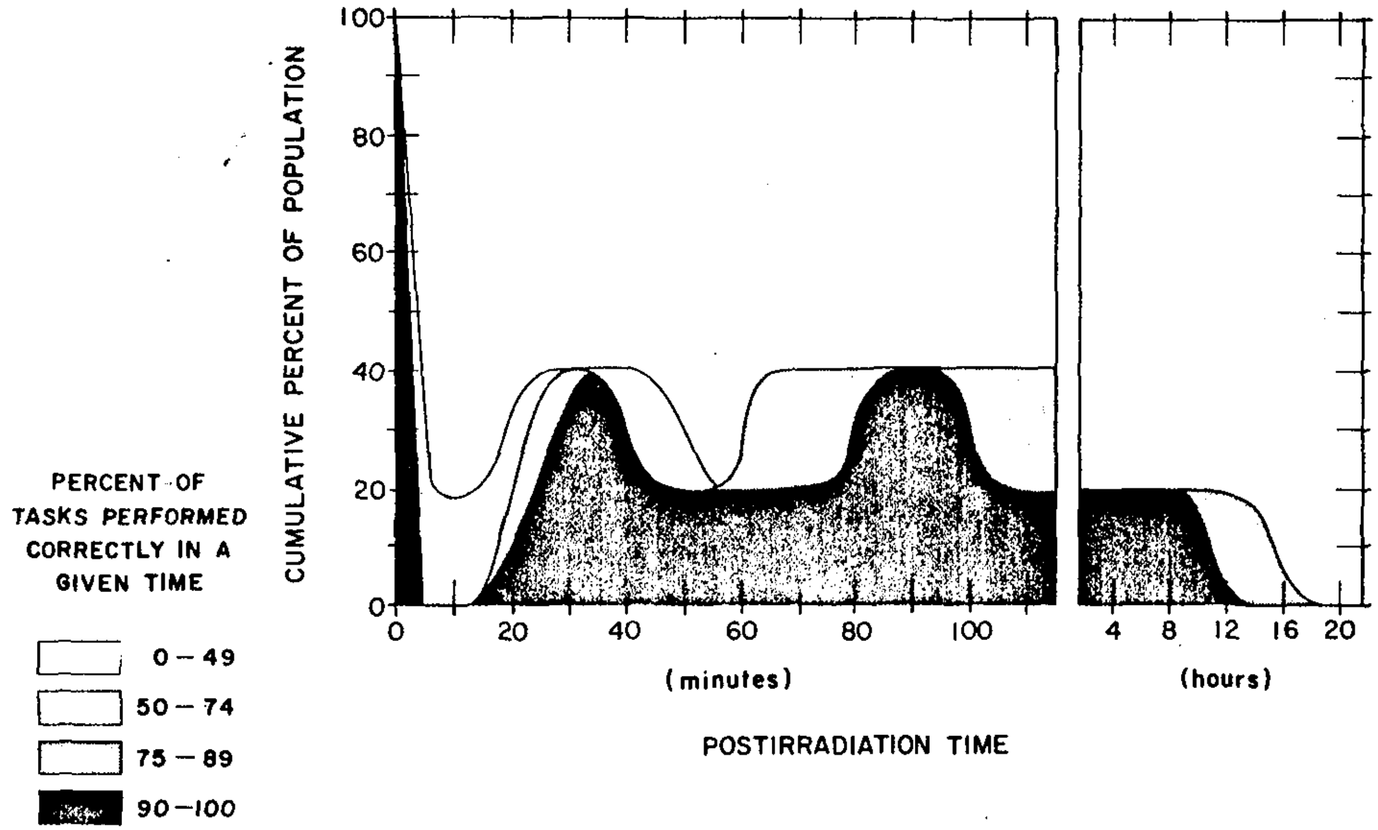


Figure 10-14. [redacted] Personnel Effectiveness After Exposure to 13,000 rads [redacted]

[redacted]

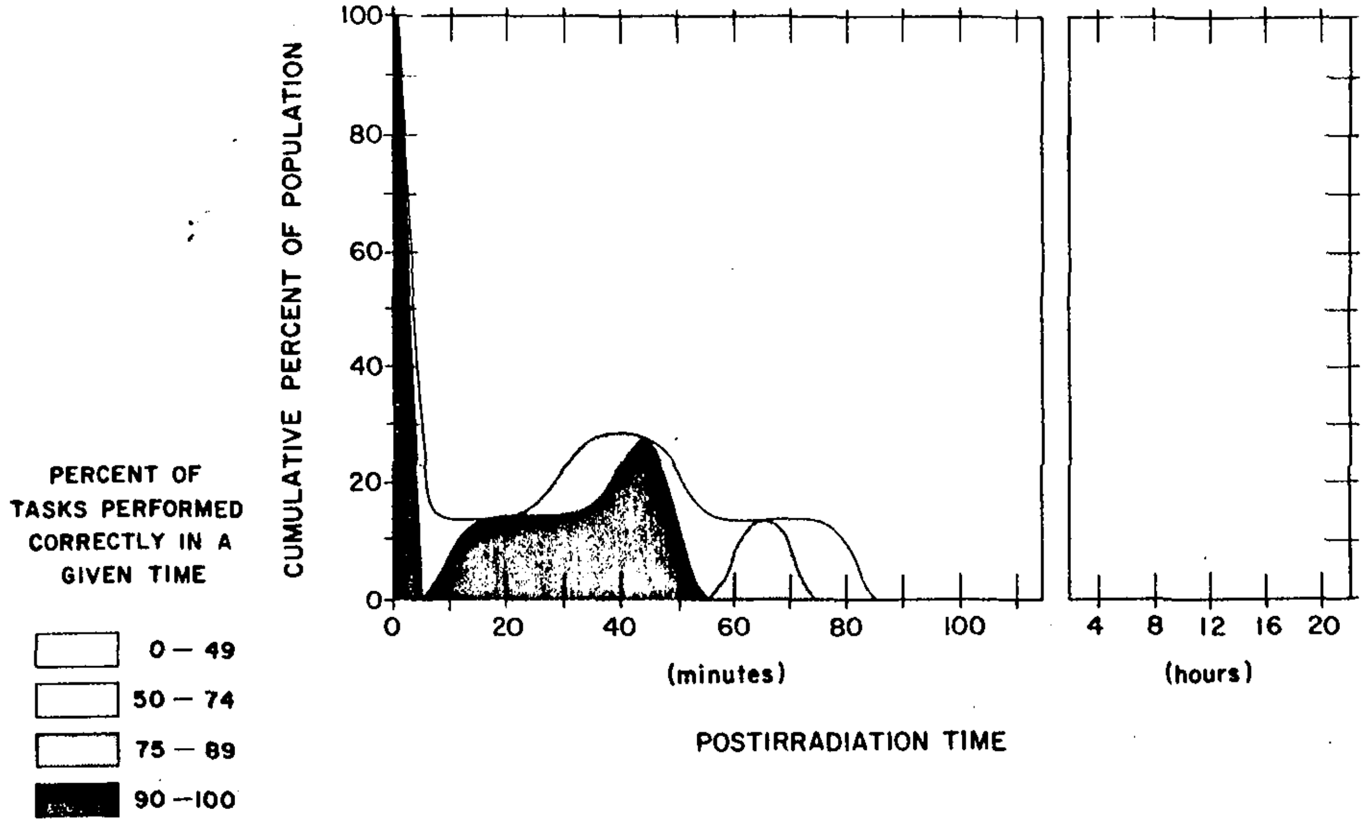


Figure 10-15. [redacted] Personnel Effectiveness After Exposure to 22,000 rads [redacted]

[redacted]

10-28 Internal Hazards [redacted]

[redacted] Radioactive materials entering the body by inhalation, eating, or through wounds or breaks in the skin may be deposited in the body where alpha particles, beta particles or gamma rays continue to bombard adjacent tissues. Once fixed within the body, removal is almost impossible, except through natural processes. Effects of internal emitters usually become apparent after a period of years, so, while of not immediate concern insofar as personnel effectiveness is concerned, this deposition may eventually be of great concern to the individual.

[redacted] Inhalation as a route of entry can be expected as the result of resuspension of radioactive materials from dust-producing activities, such as the operations of helicopter and fast-moving vehicles. Handling of contaminated equipment, supplies, and clothing may result in the hands becoming contaminated. The contamination then may enter the body while eating. Ingestion of contaminated foodstuffs and water supplies is another source of internal emitters.

10-29 Modification of Injury [redacted]

[redacted] External residual radiation can be reduced by shielding, i.e., interposition of dense material between personnel and the source of radiation, as described previously for initial radiation. Protection is afforded to varying degrees by armored vehicles, foxholes, buildings and underground shelters. However, in a residual radiation environment, it is probable that radioactive materials will be brought into the protected areas as a result of their adherence to clothing, skin, hair, and equipment. Thus, to reduce exposure, it is necessary to decontaminate both the individual and his equipment. Additionally, as much time as is militarily feasible should be spent in protected environments while the residual radiation is decaying to lower levels. Decontamination of the outer surfaces of structures also will reduce the total dose to personnel.

[redacted] If the outer packaging of foodstuffs is undamaged, they may be consumed without hazard, provided care is taken to insure that the food is not contaminated during removal of the protective covering. Cans should be washed before opening. Normal water filtration procedures will remove a majority of the fallout radioactive materials.

[redacted] Treatment of individuals showing radiation sickness symptoms from exposure to residual radiation is similar to the treatment of sickness caused by initial radiation. Burns caused by prolonged contact of beta emitters with the skin can be reduced in severity, or prevented, by early removal of the fallout material. Burns which do occur respond to conventional methods of treatment for similar burns resulting from other causes.

[redacted] Medical management of conditions arising at later times as a result of fixed internal emitters depends on the organ(s) in which the material is fixed, the number of demonstrated lesions, and the threat of this damage to life.

SECTION IV

[redacted] COMBINED INJURY [redacted]

[redacted] Thus far in this chapter little has been said about the possibility of personnel receiving multiple types of injury; however, such injuries probably would be a common occurrence in the advent of a nuclear war. Multiple injuries might be received nearly simultaneously (e.g., from exposure to a single detonation without fallout radiation) or separated in time by minutes to days (e.g., from exposure to a single detonation followed by fallout radiation, or exposure to multiple detonations). These injuries may consist of any combination of radiation, blast and thermal injuries from nuclear weapons as well as wounds from conventional weapons. Furthermore, such injuries may be influenced by other conditions that might be expected during or after a nuclear attack, such as malnutrition, poor

[redacted]

[redacted] sanitation, fatigue, and various other environmental factors. Since there are insufficient quantitative data to indicate the manner in which casualty production might be influenced by these latter factors, only combinations of pairs of the following three categories will be discussed in this section: (1) ionizing radiation injuries, (2) thermal injuries, and (3) mechanical injuries (e.g., injuries that result from blast effects).

[redacted] Most of our current knowledge concerning combined injuries is derived from studies of Japanese bomb victims in Hiroshima and Nagasaki and from laboratory and field test experiments involving a variety of animals. In Hiroshima and Nagasaki, 50 percent of the injured 20-day survivors within about 2,200 yards of ground zero received combined injuries whereas an incidence of 25 percent was observed in those located between 2,200 and 5,500 yards. The contribution of such injuries to overall mortality and morbidity has never been determined adequately, but two general impressions have emerged: the combination of mechanical and thermal injury was responsible for the majority of deaths that occurred within the first 48 hours; delayed mortality was higher and complications were more numerous among burned people who had received radiation than what would be anticipated in a burned population where no radiation exposure had occurred. It should be recognized that the stated incidences of combined injuries apply only to the conditions existing in the two Japanese cities at the time of attack and that the number and types of combined injuries are sensitive to yield, burst height, and conditions of exposure. Yields smaller than 10 kilotons probably would result in a significant number of casualties with combinations of prompt-radiation, thermal, and mechanical injuries. On the other hand, larger yields would be expected to result in a marked increase in the number of people with burns associated with mechanical injuries, and prompt-radiation injuries would be relatively insignificant in the surviving population. A weapon detonated at a burst height where fallout is minimized would result in a large number of thermal and mechanical injuries, and, depending upon yield, might also produce a significant number of prompt-radiation injuries. A weapon detonated near (above or below) the surface would maximize the number of injuries due to fallout and would produce a large number of casualties where such injuries would be combined with mechanical and thermal trauma. Personnel outside and unshielded would have a greater likelihood of sustaining prompt and/or fallout radiation in combination with thermal burns than would be the case for personnel inside of any form of structure. In the latter case, thermal burns would be minimized, whereas combinations of mechanical and radiation injury might dominate.

[redacted] Combined injuries may result in synergistic effects, additive effects, or antienergistic effects. That is, the resultant response, whether measured as percent combat ineffectiveness (CI) or mortality, may be greater than, equal to, or less than what would be predicted based on the assumption that the various injuries act independently of one another in producing casualties. Quantitative data from laboratory experiments suggests that, in situations where a combined effect has been observed, the interaction of the various forms of trauma has resulted in enhanced delayed mortality, with little apparent effect on early mortality.

10-30 Radiation and Thermal Injuries [redacted]

[redacted] Depending upon the radiation dose and the severity of burn, mortality has been found to increase by as much as a factor of six above that which might be expected from the two injuries administered singly. Thus, burns which serve as a portal of entry for infection may be considerably more hazardous to a person whose resistance to infection has been lowered by ioniz-

[redacted]

[redacted] ing radiation. However, enhanced mortality has not been observed when low radiation doses have been administered in combination with minimal burn injuries. Very little information is available on fallout radiation in combination with thermal or any other form of injury.

10-31 Mechanical and Radiation Injuries [redacted]

[redacted] Mechanical and radiation injuries can be expected to be frequent, particularly if fallout is present. Studies indicate that a delay in wound healing is observed with doses in excess of 300 rads, and that wounds in irradiated subjects are considerably more serious if treatment is delayed for more than 24 hours. In addition, missile and impact injuries that result in disruption of the skin and damage to the soft tissues would provide a portal of entry for infection, and thus may be extremely hazardous to irradiated people. Injuries that are associated with significant blood loss would be more serious in personnel who have received a radiation dose large enough to interfere with normal blood clotting mechanisms.

10-32 Thermal and Mechanical Injuries [redacted]

[redacted] Burns and mechanical injuries in combination are often encountered in victims of conventional explosions and increased delayed complications, shorter times-to-death and enhanced mortality are frequent occurrences. However, little quantitative data are available on this form of combined injury.

[redacted] CASUALTY CRITERIA [redacted]

[redacted] No reliable criteria for combat ineffectives are known for personnel receiving combined injuries. The available data do indicate, however, that individuals receiving combined injuries that occur nearly simultaneously are unlikely to become casualties within a few hours, provided the individual injuries would not produce casualties if administered separately. Consequently, it is not unreasonable to make early casualty predictions for a single nuclear detonation on the basis of the most far-reaching effect. In regard to troop-casualty predictions, combined effects can be considered as a bonus, helping to assure the attainment of predicted CI levels, especially since there is a reasonable amount of uncertainty in the predictions for individual effects. If exposure exceeds any "minimal" risk level, that effect could contribute to combined injury and could result in increased casualties at later times. This becomes an important factor in terms of troop safety.

[redacted] PERSONNEL IN THE OPEN [redacted]

[redacted] Figure 10-16 indicates expected burn levels, prompt ionizing-radiation doses, and peak translational velocities as functions of yield and ground distance for randomly-oriented, prone personnel exposed in the open. The curves were derived, assuming a visual range of 16 miles and a burst height such that the fireball would just touch the surface. This is the minimum height of burst which would result in negligible early, or local, fallout. The curves, which are presented for illustrative purposes only, form the limits of a band for each effect. These limits correspond to 50 percent early casualties and "minimal" early risk. The ionizing-radiation dose required to produce 50 percent CI within one hour, e.g., approximately 5,000 rads, is so large that it will result in 100 percent mortality within several days. For this reason, a 500-rad curve, which would correspond to approximately 50 percent mortality within 60 days, is included in Figure 10-16. Direct overpressure effects are not included in the figure since, except for eardrum rupture, which is not normally considered to produce CI, translational effects extend to greater ranges for all of the yields considered.

[redacted] In the case of troop-casualty predictions, prompt-radiation predominates for yields less

[redacted]

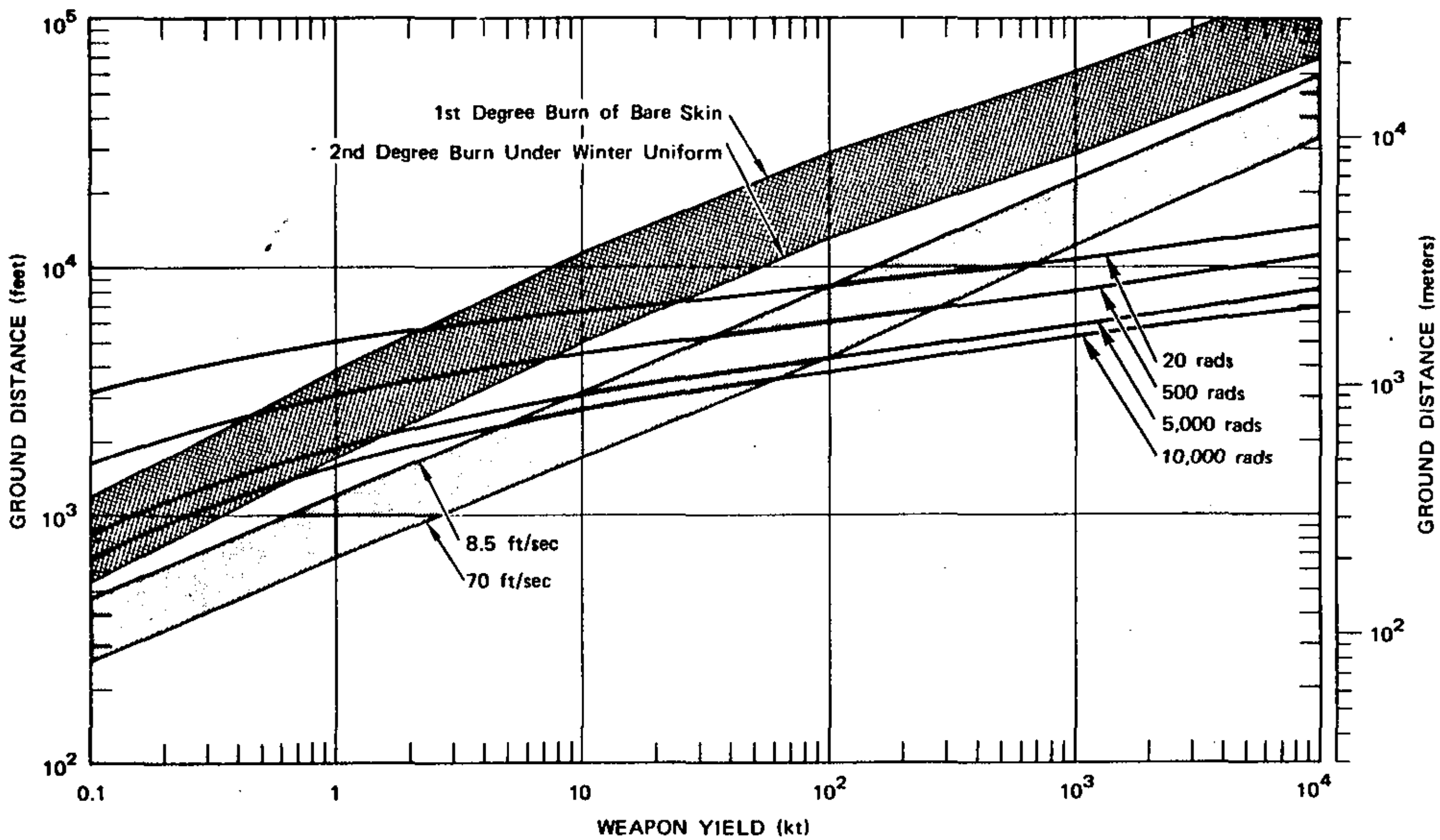


Figure 10-16. [redacted] Comparison of Effects from Low Altitude Bursts [redacted]

[redacted]

[redacted]

[redacted] than 2 kt whereas thermal radiation is the most far-reaching hazard for yields greater than 2 kt. In situations where thermal exposure is neglected as a casualty-producing factor, ionizing radiation is the major effect in producing a 50 percent CI level for yields below 100 kt, while for larger yields, blast effects (translation) predominate.

[redacted] With regard to troop safety, ionizing radiation is the major hazard below 1 kt, while thermal radiation predominates for larger yields. If the troops can be shielded adequately from the thermal pulse, ionizing radiation is the major hazard for yields up to 100 kt, above which blast effects are the most far-reaching hazard.

[redacted] PERSONNEL IN STRUCTURES [redacted]

[redacted] In order to predict casualty levels for troops in situations other than open terrain, for example, inside armoured vehicles or field fortifications, the amount of nuclear radiation, thermal radiation, and blast shielding, as well as the degree of blast hardness of the surrounding materials must be taken into account for each geometry of exposure. As was the case for personnel in the open, casualty predictions must be made on the basis of the most far-reaching single effect rather than on the basis of combined effects. In general, for troops in structures, the major effect producing early casualties is likely to be ionizing radiation for small yields and blast effects for larger yields, with the cross-over point depending on the degree of hardness of the structure. While the hazards from thermal and ionizing radiation levels are reduced in a structure, the hazards from air blast may be magnified as a result of structural collapse, whole-body impact, and falling debris. This is particularly true for relatively soft structures at greater distances.

[redacted] In the case of personnel in field fortifications, severe damage to the structure (Section VI, Chapter 4) should be taken as representative of 50 percent early CI from blast. Shielding factors (Section VI, Chapter 9) must be considered when estimating nuclear radiation responses of personnel in such structures.

[redacted] TREATMENT [redacted]

[redacted] The triage and treatment of combined injuries present special problems, particularly if significant radiation exposure has occurred. Certain modifications in accepted medical and surgical practices must be considered since radiation exposure, depending upon dose, is known to increase susceptibility to infection, to decrease the efficiency of wound and fracture healing, to increase the likelihood of hemorrhage, to decrease tolerance to anesthetic agents, and to decrease the immune response.

[redacted] It is imperative that primary closure of wounds be accomplished at the earliest possible time and that patients be treated with a broad spectrum antibiotic throughout the period of maximum bone marrow depression. Secondary closure of small soft-tissue wounds should be accomplished by the second or third day. Reparative surgery of an extensive nature should not be performed later than four to five days after injury since skin and soft-tissue healing should have occurred before the effects of ionizing radiation occur. If reparative surgery is not performed within this limited period of time, it must be postponed until the bone marrow has recovered (one to two months post-exposure). Wounds of injuries that require longer than three weeks for healing, such as severe burns and most fractures, should not be definitively treated until radiation recovery is evident. Although reconstructive surgery in the absence of radiation exposure might be performed within the second month or earlier after conventional trauma, it must be postponed for at least three months in instances where radiation exposure is a significant contributory factor. In all instances, extra precaution must be taken to avoid infection and blood loss.

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